DEPARTMENT OF
SCIENTIFIC AND INDUSTRIAL RESEARCH

FOREST PRODUCTS RESEARCH 1955

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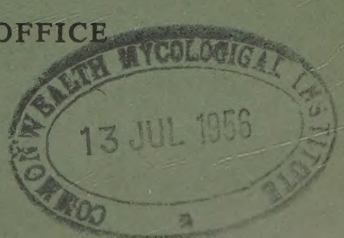

DEPARTMENT OF
SCIENTIFIC AND INDUSTRIAL RESEARCH

Report of the Forest Products Research Board

with the Report of the Director
of Forest Products Research
for the year

1955

LONDON
HER MAJESTY'S STATIONERY OFFICE
1956

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1955

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REPORT OF THE FOREST PRODUCTS RESEARCH BOARD FOR THE YEAR 1955

To the Lords of the Committee of the Privy Council for Scientific and Industrial Research

MAY IT PLEASE YOUR LORDSHIPS,

WE, the Forest Products Research Board beg leave to present our report for the year ending 31st December, 1955.

The year, although a very busy one, has brought no significant changes in the general trend of the work of the Laboratory. The major commitments of testing and assessing new Colonial timbers have engaged all Sections, and an increased number of selected parcels of home-grown timbers from the Forestry Commission's plantations has been examined and reported upon. Although these reports on home-grown timbers are of interest in themselves, and the yearly number of tests will be augmented as staff and time permit, yet the project is still, and will for some years continue to be, in its exploratory stage. It is too soon to lay down a closely-defined and co-ordinated programme of work with the foresters. All the time, however, the plantations are moving towards maturity, and the problems of utilization have to be anticipated. One of these is the question of the grading of the home-grown timbers, both softwoods and hardwoods. We are glad to report that an *ad hoc* Committee convened by the Laboratory, and including representatives of the softwood users, the Royal Institute of British Architects, the Timber Development Association, and the Forestry Commission, has formulated a set of recommended grading rules for home-grown softwoods. Following publication of the rules, two of the Laboratory's officers have paid a visit to the Scandinavian countries to gain first-hand knowledge of the methods employed in the seasoning and grading of their softwoods, which form a considerable part of our imported timber.

It has been possible, also, during the year, to devote more time to industrial surveys. Two of these have been undertaken—a survey of the woods used for musical instruments, requiring a comprehensive programme of visits, on which a report is now being prepared, and a survey of the railway wagon and coach-building trade. A similar survey of the sports goods industry is in view.

In his report, the Director deals in detail with the activities of the various Sections of the Laboratory. Of these, we select the following as being of special interest:

TIMBER IDENTIFICATION

The satisfactory identification and description of timbers is a matter of considerable importance to shipper and importer alike, particularly when many closely allied species are shipped under different names from various countries where they grow. Such identification requires the collation and conjunction of the work

of the forest botanist and the wood anatomist. A particularly complex group is that of the Dipterocarp timbers from South-East Asia, and work at the Laboratory on this group has progressed far enough to justify the publication of a new research bulletin on Meranti, Seraya and allied timbers from the region.

SEASONING

In addition to investigations on the seasoning of various species, work has continued on the examination of the factors influencing the behaviour of timber during seasoning. The following investigations have been completed during the year: the effect of air speeds on drying rates; the transference of heat from air and steam to a water surface; and high-temperature drying. Some industrial applications of radio-frequency drying have been carried through with the co-operation of the firms interested in the process.

PLYWOOD BENDING

The large-scale investigation of the bending of African mahogany plywood has been completed and further work is in hand to determine the influence of various factors on the stability of plywood bends.

TIMBER STRUCTURES

A number of interesting papers have been published on research projects on timber structures. The formulation of new grading rules for softwoods has already been mentioned, and experiments on long-term loading are now yielding results. The investigation on the strength of timber struts mentioned in our last report has led to a further one on the strength of struts subjected to combined compressive and bending loads. On timber joints, also, papers have been published on properties of connector joints, nailed joints, and glued joints, and two bulletins have been issued on the strength properties of plywood. The results of a study of design methods for plywood forms for concrete have been published in the technical press.

On the strength of timber itself two investigations have been completed and reported upon. One of these concerned the effect of kiln-drying by superheated steam on the general strength properties, and the other the effect of depth on the strength properties of beams.

In the field of laminated timber construction a special report has been published on the theory of design of two-species laminated beams, and work is in hand to establish design procedure for application in laminated timber constructions.

WOODWORKING

The research projects on aspects of full-scale woodworking processes have continued, but especial attention has been focused on the intimate relations between the timber and the cutting edge. On the one hand, further work has been done to elucidate the process of chip formation, and by means of special apparatus the observations on rectilinear cutting, previously made at slow speeds, can now be carried out at speeds comparable with those of a normally operated saw. Further knowledge has already been gained on the failure of the wood near the cutting edge and the details of the formation and dimensions of the chips. A

cognate study on the blunting of planer cutters and the estimation of their wear is the subject of a special report which has been prepared during the year.

PROPERTIES OF ADHESIVES

During the year one of the long-term durability trials on plywood adhesives has been completed, and the results published. This test, of five years' duration, was carried out partly in England and partly in Nigeria using plywood of beech or gaboon bonded with a range of the adhesives.

New durability experiments which include not only glues in present-day use but also some still in the development and experimental stages have now been started, and a range of specimens of plywood and assembly joints is undergoing exposure on the weathering site at the Laboratory.

BOND QUALITY IN PLYWOOD

The assessment of the quality of the bond in a plywood by the "Knife test" has, after lengthy trials, been rendered relatively free from the element of personal judgment. The appearance of the test-piece, in which the plies are inspected after their disruption by a specially shaped knife, can now be assigned a numerical value denoting the bond quality in terms of a master scale.

MOISTURE CONTENT DETERMINATION

The possibility of determining the moisture content of veneers by the use of radioactive isotopes has been studied with the help of the Isotope Division at Harwell, but has not proved to be feasible.

PERMEABILITY OF TIMBER

In connection with research in Wood Preservation, a study has been completed of the longitudinal permeability to air of about a hundred species of wood. The range of permeability has proved to be remarkable, the variation being about one to five million with the hardwoods and about a tenth of this with softwoods. In the hardwoods, a correlation has been established between their permeability and their durability.

RAILWAY SLEEPER INVESTIGATIONS

Of the experimental test groups of sleepers laid in the track some 20 years ago only one remains to be finally examined. Sleepers were removed from two sites and examined during this year, and they have, in general, confirmed the observations already made on those from other sites as to the advisability of obtaining good penetration of preservative into the heartwood face, and of laying sleepers heart face up to obtain a longer mechanical life.

MYCOLOGICAL WORK

Interest has again centred on the group of fungi causing soft-rot, and investigations are continuing on their physiology and also on the more practical aspects of their power to cause decay in various species of timber, and their activity in the breakdown of wood in water-cooling towers, wooden craft, and elsewhere.

Also included in current projects in Mycology are tests on the leaching-out of water-soluble preservatives, and the efficacy of fungicidal solutions in contact

with mortar and bricks. A second experiment on the protection of beech logs by means of antiseptic coatings has been completed, and the report has appeared in the technical press.

ENTOMOLOGICAL WORK

Much of the year's work has been carried out on the long-term investigations of the life-history, the nutrition, and the behaviour of the chief wood-destroying insects. Tests on destruction of the insects by some of the newer methods are in hand, and include treatment of the timbers by gamma rays and by high-frequency currents.

Close contact with the West African Timber Borer Research Unit has been maintained, and the member of that unit stationed at the Laboratory is investigating the biology and food requirements of the oak pinhole borer in this country.

WOOD CHEMISTRY

The chief basic studies of the year have concerned the hemicelluloses of beech, the oligosaccharides in Scots pine, and saponins in morabukea. Work has also been done on the extractives of some tropical timbers.

CORROSION

In view of the present active interest, a series of trials has been instituted, in co-operation with the Aluminium Development Association, to gain information on the corrosion of aluminium products in contact with wood, both untreated and treated with preservatives. Experiments have also been carried out to ascertain why metal parts in certain wood/metal assemblies become corroded when they are exported to tropical countries.

HARDBOARDS FROM TROPICAL TIMBERS

Two papers have been published on the production of hardboard from four Malayan timbers, and further work has evaluated methods of improving the water-resistance of boards made from certain tropical woods.

TIMBER PHYSICS

Investigations on the fundamental physical properties of timber have continued during the year, and include studies on moisture movement and distribution in wood; elastic and allied properties, and specific heat and heat of wetting.

ADVISORY SERVICE

Advisory work continues to be a most important feature of the Laboratory's work and the Director's report discloses its remarkable scope and variety. This year, although the figure for technical enquiries has been maintained, there has been a sudden and significant fall in the simpler type of entomological enquiry, due, presumably, to the increasing commercial service offered to the public. A lessening of pressure in this type of advisory work is welcome as the time saved can be more profitably used. There is, we are pleased to note, no decline in technical enquiries, which enable the Laboratory not only to give a valuable service but also to keep in close touch with industry, and which are a fruitful source of ideas for research.

VISITORS AND EDUCATION

Once again the number of requests for visits of parties to the Laboratory has exceeded the number which could be met, and preference has had to be given to those institutes and associations to whom the visits were likely to be of most value. The customary courses to staff members of Service and other government departments, to other bodies, and to university forestry undergraduates were held, and the usual courses for kiln-operators were given. There have been 74 visitors from 28 different countries overseas.

MEMBERSHIP OF THE BOARD

In April, 1954, Professor J. Walton had to withdraw from the Board because of illness, and on completion of their periods of membership, Professor W. T. Astbury, Mr. D. Booth, and Mr. Paul Williams retired from the Board in March, 1955; we wish to acknowledge the valuable service they have rendered to the Laboratory.

We are glad to welcome Professor J. R. Matthews, Mr. E. D. Mills and Mr. C. A. B. Tait as new members of the Board.

R. G. BENNETT,

February, 1956. *Chairman.*

REPORT OF THE DIRECTOR OF FOREST PRODUCTS RESEARCH FOR THE YEAR 1955

INTRODUCTION

DURING 1955 there has been little change in the general direction of the work of the Laboratory. In the continuing projects in all sections research on timbers and processes has gone steadily on, and the volume of advisory and short-term work shows no decrease. Following the trend of the past few years, the proportion of effort spent on the testing and evaluation of home-grown species on behalf of the Forestry Commission has again increased, and will continue to do so. Although these continuing commitments make a heavy call upon staff time, there has been some welcome increase in the amount of basic research in hand, and it has also been possible this year to extend the amount of time spent in surveys of the wood-using industries.

With outside bodies and institutions, commercial firms, government departments and the general public our relations remain excellent, and the service afforded by members of staff to various advisory and technical committees is undiminished.

GENERAL

TAFF, BUILDINGS AND EQUIPMENT

There has been a small increase in staff, the structure and proportions of which, however, remain essentially unchanged.

No major alterations or additions to the Laboratory's buildings or equipment have been made during the year.

TOURS ABROAD

In July, the Officer-in-Charge, Chemistry Section, attended a symposium in Dublin arranged by the Institute of Chemistry of Ireland on recent advances in the chemistry of naturally occurring pyrones and related compounds. In the same month, accompanied by a senior officer of the Section, he visited Zürich to attend the Fourteenth International Congress of Pure and Applied Chemistry. The opportunity was taken to visit firms concerned with methods for utilization of waste wood.

In June and July a tour of research laboratories and commercial establishments in the Scandinavian countries was made by the Officer-in-Charge, Seasoning Section, and an officer of the Timber Mechanics staff. Their object was, on the one hand, to bring up to date the Laboratory's knowledge of the practice of timber seasoning in these countries and, on the other, to examine their methods of conversion and grading, having in mind the rules recently formulated by the *ad hoc* Committee set up by the Laboratory on the grading of home-grown softwoods. A comprehensive programme of visits and discussions had been arranged for the visitors, and much useful information was gained. Thanks are due to all those in Norway, Sweden and Finland who so unreservedly contributed to the success of the tour.

PUBLICATIONS AND RECORDS

In addition to the Annual Report for 1954, new Stationery Office publications issued during the year include two Bulletins, two Special Reports, and one Leaflet—"Grading of Sawn British Hardwoods"; revised editions were also published of five other leaflets. Bulletin No. 35, "The Machine Boring of Wood" describes tests on various species of hardwood and softwood to relate the performance of the boring bit to the cutting conditions and the growth characteristics and grain orientation of the wood. Special Report No. 9, "The Strength of Timber Struts" is concerned primarily with the effect of knots on the strength of struts, of the type used in light constructional work, in relation to various theoretical formulae. Special Report No. 10, "Laminated Beams from Two Species of Timber: Theory of Design" presents suitable methods for designing two-species beams. The latter consist of relatively thin outer laminae of a strong, dense species glued to the core of a weaker, lighter one. A theoretical analysis of the stresses in a beam under load is given and from this equations for determining strength are evolved. In addition it is shown how beam sections of minimum cost and minimum weight can be found for any two species.

The output of printed publications in 1955 will be found in Appendix II. In addition 30 reports on various subjects were cyclostyled for limited distribution, including 16 on plywood and 9 on the properties of thinnings of various species from Forestry Commission plantations.

ADVISORY SERVICE

The number of direct contacts, mainly through outside visits, visitors to the Laboratory and communications by mail and telephone, has been maintained at a high level. In addition to the more general means of dissemination of information by the Laboratory as a whole, each Section has continued to keep in constant touch with those fields of industry which it mainly serves, and a great deal of information has been exchanged in personal discussion. For the many enquiries of a routine nature which do not require following up, the standard leaflets issued free by the Laboratory continue to carry information to many thousands of people annually. The number of enquiries answered by letter during the year was 5246; the number of leaflets issued to the public directly or at exhibitions was 33 007.

PROGRAMME OF RESEARCH

WOOD STRUCTURE

Collection of Timber Specimens

Nearly eight hundred specimens have been added to the Laboratory's reference collection during the year and an appreciably larger number of duplicate specimens has been distributed, mainly to institutions concerned with research or teaching. Acquisitions of special interest are two collections from the island of Borneo, 225 specimens collected in the swamp forests of Sarawak, and 289 specimens from North Borneo. Nearly all are correlated with herbarium material; they are of particular value as they come from an area of increasing commercial importance, so far as timber is concerned, where rapid advances are being made in botanical knowledge of the trees and their timbers. Thanks are

due to the staff of the Forest Departments concerned for the onerous work of collecting, transmitting and identifying these specimens.

It is of interest to recall that it is twenty-five years since the classified reference collection of timber specimens was started in the new Wood Structure laboratory. The number of specimens catalogued during this period is over twenty-three thousand but the representative nature of the collection is indicated better by the number of species, which is estimated to be between six and seven thousand. Many of the timbers acquired and classified in the early years were of no economic significance at the time and much of the work involved was of no immediate value. However, the policy of building up an extensive collection of world timbers, instead of restricting it to species of contemporary economic importance, has been amply justified in a period of radical changes in the timber situation. At no time was the collection more useful than during the Second World War and the post-war era, when scores of practically unknown timbers had to be purchased in all parts of the world to meet the country's essential requirements. An invaluable indication of the technical properties and uses of these timbers was obtained from the Laboratory's specimens and the technical records associated with them.

In the Report for 1931 (p. 4) reference was made to the small proportion of authentic specimens of guaranteed specific identity in the collection and the difficulty of obtaining material correlated with leaves, flowers and fruit from the same tree. It is gratifying to be able to record that for some years past it has been the general rule for timber specimens supplied by forest departments to be correlated with herbarium material determined by a competent botanist and filed for permanent reference. Consequently, the proportion of reliably named material in the collection has greatly increased; it has recently been estimated that approximately 35 per cent of the specimens in the main working collection are botanically authenticated.

The collection also includes a large number of commercial samples, many of them acquired through the co-operation of importers, timber merchants and others. Although these are not authentic in the botanical sense, they serve to extend our knowledge of the normal range of variation in the timbers concerned; in fact the practical value of the reference collection depends on its including a proportion of such material to supplement the main series of botanically authentic specimens.

Exhibit Collection of Specimen Boards

A feature of the corridors in the main building of the Laboratory is the exhibit collection of 6-ft. specimen boards, which has recently been extended and rearranged (Plate 1). It numbers nearly 250 specimens and includes most timbers of commercial importance in the United Kingdom. Many of these specimens have been generously presented by members of the timber trade. This exhibit collection also includes 18-in. panels of the principal commercial timbers, which are in continual demand for demonstrating to visitors and for exhibitions and lectures.

Advances in the Classification of Commercial Timbers

Timbers of closely allied botanical species may be very similar in technical properties and practically indistinguishable; in other cases the differences may be

considerable. For purposes where minor differences are unimportant, as in heavy constructional work, a number of closely allied species may be used without distinction. For more exacting purposes, however, the differences may be such that it is desirable to separate the species concerned. Thus, advances in our knowledge of the properties of related species may lead to improvements in the quality of the timber offered to the consumer, if it is feasible to separate the different species in the course of production. This process of progressively improving the quality of commercial timber depends on botanical and technological studies of the trees and the timbers, in the forest, the herbarium and the laboratory, as also the results of practical experience in the manufacture and use of the timber.

Timbers derived from a group of allied species are continually being studied as their botanical classification is clarified and as reliably named material becomes available for examination. The acquisition of authentic material has, for instance, made it possible to differentiate between the species included in commercial consignments of Chilean manio. It is now clear that the species known as manio macha (*Saxegothaea conspicua*) is an important constituent of the export timber, together with two or three species of *Podocarpus*. Investigation has shown that some of the variation in the quality of commercial manio is due to this mixing of species. It has been found, incidentally, that the Chilean species of *Podocarpus* are of two anatomical types, both different from the East African species.

A somewhat similar investigation has been concerned with a group of tropical African timbers including bubinga or kevazingo and a number of other decorative hardwoods which have been the subject of inquiry. The species concerned have been sorted out and an account of their botanical identity, structure and technical characters has been published[1].

Again, recent research has shown that the sepetir of Sarawak is botanically distinct from the Malayan timber of the same name. Laboratory investigation of the timbers has revealed that they differ significantly in structure and physical properties and should be regarded as different timbers for commercial purposes.

Meranti, Seraya and Allied Timbers

For several years work has been proceeding when time permitted on a revision of Forest Products Research Record No. 12, "Seraya, Meranti and Lauan", published in 1936. Since the end of the Second World War the development of the timber resources of South-East Asia has enhanced the importance of the Dipterocarpaceae in the world market but there is still considerable confusion between the numerous closely allied species shipped under different names from various countries. In recent years notable advances have been made in our knowledge of the trees and their timbers by investigators in Malaya, North Borneo, Sarawak and Indonesia. The task of co-ordinating the published information in conjunction with extensive laboratory studies of the timbers has now reached the stage where a new publication[2] on the timbers of *Shorea*, *Parashorea*, *Pentacme* and *Anisoptera* can be prepared to replace the old Record No. 12. It must be emphasized, however, that much remains to be done before the timbers of this difficult group are sorted out so as to ensure their most effective use.

Variation in the Timber of Shorea albida

An unusual case of variation due to conditions of growth has been investigated. *Shorea albida*, a timber tree of some importance in Sarawak, is credited with producing two types of timber, a hard, heavy type known locally as alan, and a light-weight, meranti type known as meranti bunga and so different from alan that it was thought it might be a distinct botanical variety. Field investigations by officers of the Sarawak Forest Department showed that *Shorea albida* occurs in three fairly distinct forest types and a series of wood samples from representative trees was supplied to the Laboratory. Examination of these has confirmed that the timber exhibits an exceptionally wide range of variation in weight, light wood being laid down during the early years of growth and dense wood later in life. A wide variation in weight was found in material from each of the forest types; it seems that under certain conditions trees produce mainly light-weight core-wood (meranti bunga) while elsewhere the proportion of core-wood is small and the bulk of the timber is of the alan type. Indications are that the proportion of light-weight wood is correlated with the vigour of the tree in early life.

Tension Wood, a Natural Defect of Hardwoods

It is a commonplace that the successful use of timber for exacting work depends not only on the selection of suitable species but also on the elimination of defective material from the higher grades. A natural defect that may be found in many kinds of hardwood is tension wood, an abnormal type of wood occurring typically on the upper tension side of trees that are growing out of the vertical, as is often the case on steep hillsides or in consequence of exposure to the prevailing wind or from various other causes. Tension wood has been known to wood technologists for a long time but it is not generally recognized as such by timber users. It is, however, sometimes of considerable practical importance as it is apt to cause distortion, splitting and collapse in seasoning and difficulties in machining and finishing. Judging by the number of enquiries received it seems that tension wood has recently become more common in commercial timber, possibly because of the need to utilize more second and third quality trees and top logs, which in former times would be left in the forest. To draw attention to the desirability of recognizing it as a defect a non-technical, illustrated article has been prepared for publication[3]. A typical example of tension wood is shown in Plate 2.

Growth Studies: Illumination and Lignification

From previous experiments on the physiology of wood formation it seems clear that the substance responsible for initiating lignification is of a fugitive nature, and is not stored, or at least does not remain effective, over the winter, since lignification of the new growth in the following season was shown to be dependent on the activity of the fresh crop of leaves. Nevertheless, some evidence has now been obtained that the "lignification substance" may be accumulated in the course of the growing season, so that towards the end of the summer a sufficient reserve is available to permit lignification to proceed even if the leaves are then kept in darkness. This is not so if the leaves have been starved of light during the major part of the season, thereby preventing a build-up of the "lignification substance": in this case subsequent full illumination fails to induce

proper lignification of the later summer-wood fibres. Further work on this subject is in progress.

Miscellaneous Work in Wood Structure

There has been further co-operation in the editing of Part II of the British Commonwealth Forest Terminology on utilization, timber trade and forest products research, sponsored by the Empire Forestry Association.

The Laboratory has also co-operated in the revision of the British Standard Nomenclature of Commercial Timbers, which was published during the year.

Many requests for the identification of timbers have concerned inferior species being included in parcels of imported timber, indicating the need for more care and discrimination on the part of the shippers.

The timbers used in a number of manufactured articles imported from abroad have been identified for the information of firms manufacturing similar goods in the United Kingdom.

The identification of wood splinters found in a food product enabled the source of the contamination to be traced.

Requests have been received for information and advice on timbers offered to importers by overseas shippers. It is noteworthy that hitherto unknown timbers that are quite promising for the export market are still being discovered in various parts of the world. Certain other timbers offered have had little to commend them for the United Kingdom market, however, and in such cases importers have been advised accordingly.

Advice on the suitability of local timbers has been supplied to several countries engaged in developing their own industries to manufacture goods hitherto imported ready made.

There has been the usual number of enquiries about defects in timber and failure of manufactured articles in service, as to whether they are due to natural causes (growth defects) or to subsequent treatment or to the use of an unsuitable species.

The number of external enquiries involving a written reply amounted to 453. Altogether over 1200 specimens have been identified in the course of the year, about 900 of them in response to outside enquiries.

SEASONING

Kilns and Kiln Seasoning

Investigations on the seasoning properties of the various species have continued and large kilns have been used during the year for the drying of loads of niangon, jelutong, African walnut, dahoma, beech and Indian rosewood. The niangon seasoned well with virtually no degrade and strips sawn from the dried material showed little tendency to distort. Its general behaviour, in short, was considerably better than that of some consignments previously tested. The smaller kilns have been used for drying experimental loads of muchenche, kapur, African padauk and two species of red seraya (*Shorea smithiana* and *S. parvifolia*). In addition two loads of $1\frac{1}{4}$-in. home-grown beech were kiln dried in board form and two matched loads in the form of $1\frac{1}{4}$-in. by $1\frac{7}{8}$-in. curved sawn material for chair legs. These tests were undertaken in co-operation with a firm

of furniture manufacturers to determine the most satisfactory and economical method of seasoning material for this particular purpose. Results so far favour the drying of the roughly-shaped material.

Many of the kiln schedules recommended by the Laboratory have recently been revised and in connexion with this two matched loads of English elm consisting of boards 1¼ in. thick have been dried at low temperatures, the first with an initial humidity of 80 per cent and the second with an initial humidity as low as 70 per cent. The time required to dry the wood according to the lower humidity schedule was 14 days as compared with 18½ days at the higher one; there was very little difference in the final quality of the timber after drying to 12 per cent moisture content. In the series of tests on the seasoning properties of home-grown softwoods, loads of lodgepole pine, Douglas fir, grand fir and Sitka spruce have been dried. Several loads of home-grown softwood have also been dried in the large kilns to provide material for tests on cable drums.

High-temperature Drying

No further work has been carried out during the year on the drying of timber at very high temperatures. An article on the findings to date has been published.

Appendices to the report prepared last year on the high-temperature drying of African mahogany have been published, dealing respectively with the effect of high-temperature drying on the equilibrium moisture content and movement of the dried timber, and with the kiln drying at high temperature of African mahogany which had previously been air dried to a moisture content of 23 per cent. It was shown that both the equilibrium moisture content and the movement values for this timber after it had been dried at high temperatures are appreciably lower than for the same timber dried in accordance with a normal schedule. The air-dried material, 1½ inches thick, was dried in 45 hours to a final moisture content of 9 per cent and behaved well, significantly better indeed than similar timber dried at high temperatures direct from the green condition.

Tests on the Effect of Air Speeds on Drying Rates

Work has continued on this series of tests and stacks of 1-in. beech, English oak and Corsican pine each 10 ft wide have been dried in the experimental kiln built for the purpose. Drying lags across the pile have been determined for various air speeds up to 12 ft per second for both unidirectional and periodically reversed air flow. As might be expected, the effect of air speed on the overall drying times was found to be more marked with the fast-drying species than with the slow.

An article[4] has been published on the results obtained for the drying of the beech and the Corsican pine with special reference to the effect of reversal of air flow upon the drying schedule.

Radio Frequency Drying

Following experiments by orthodox kilning methods[5] work has been carried out on the drying of birch broomheads in the round by means of radio-frequency heating. It was not required to dry these to a very low moisture content and little splitting or other form of defect occurred. This method of drying broomheads has since been developed commercially with some success by the firm co-operating in these experiments.

Experiments carried out on the radio-frequency drying of beech scantlings and roughly shaped blocks for the manufacture of shoe heels have been carried out in co-operation with a well known firm of shoe makers. Results were promising and the economic aspect of the process is being examined by the firm.

Evaporation Tests

A series of tests has been carried out to investigate the effects of temperature, humidity and air speed on the rate of evaporation from a free surface of water. Evaporation rates with air and steam temperatures up to 107·5° C were determined.

Results indicated that (a) there was an increase in the coefficient of heat transfer from the heating medium to the water surface with increasing temperature and increasing humidity and (b) there was no marked sudden change at the boiling point temperature of 100° C (212° F).

A report on these tests has been published[6].

Distortion Experiments

Tests have been put in hand to study the effect on the subsequent distortion of timber samples of subjecting them to mechanical restraint during the drying process. Results so far obtained on beech and African mahogany samples indicate that on release of the restraint some distortion occurs immediately, and that for a period of several weeks thereafter this distortion tends gradually to increase even though the samples are kept at constant moisture content. This tendency was particulary marked with the African mahogany, the ultimate distortion of the restrained samples being a little less than that of matched samples which were free to distort as they dried. The maximum distortion of the restrained beech samples was, however, less than half of that of the unrestrained controls. The tests on beech also indicated that distortion was reduced to a greater extent when the drying was conducted at 150° F than when it was carried out at 77° F.

Miscellaneous Tests

Small-scale tests have been made to compare the shrinkage of brown sterculia sapwood with that of adjoining heartwood; to examine the distortion which occurred under changing atmospheric conditions on various flush doors; and to obtain information on the drying of thin cross-sections cut from round timber.

Wood Bending

Solid Bending.—The routine testing of timbers to determine their steam-bending properties has been continued and data on some nine different species obtained, including muchenche, purpleheart, East African mulberry, Tasmanian myrtle, and French ash. The bending properties of the French ash were found to be slightly better than those of the home-grown variety and reasonably promising results were obtained with both the mulberry and myrtle. In view of this, further consignments of the last two species are being obtained for supplementary tests.

Reports have been prepared on all species tested to date and details have been published of the equipment and methods used at the Laboratory in wood-bending tests, and also on the new type of steam retort developed recently. One firm has reported that as a result of using the improved softening procedure bending breakages have been reduced from 30 per cent to 5 per cent.

An improved method of applying end pressure when making bends on commercial-type bending machines has been developed, employing hydraulically-operated rams. These apply an end-thrust to the ends of the steamed blanks by means of a metal-studded plate fitted into the end of the supporting strap and as a result the end pressure can be adjusted and controlled throughout the complete bending operation. The method is illustrated in Plate 3.

Conventional methods of setting solid bends are comparatively slow and attention has therefore been directed to developing a method of accelerating the process. Promising preliminiary results have been obtained by setting the bends on heated bending jigs and further work is in progress.

Miscellaneous work has included the development of suitable methods of producing solid bends containing re-entrant angles; special tests on utile for a furniture manufacturer; the bending of ebony umbrella handles; and the production of small-radius plywood bends by the recently patented method which incorporates a balsa insert on the concave face of the bend.

Laminated Bending.—In the field of laminated bending, basic data on the limiting radii of curvature of fifteen different hardwoods have been obtained. Further tests have also been made on the suitability of radio-frequency heating methods for setting resorcinol resin glues in laminated oak assemblies. Difficulties have been met in obtaining consistently good adhesion but it is not certain that this is owing to the heating process employed. There is evidence that some consignments of oak glue satisfactorily with this resin, while others do not. The matter is being investigated further.

Tests have been begun to determine the spring-back or outward movement of laminated bends when the glue-pressure clamps are removed. Formulae for calculating such movements have been evolved and are to be verified by practical tests.

Plywood Bending.—The large-scale investigation on the bending of African mahogany plywood has been completed and a report prepared. Tests to determine the influence of various factors on the setting to shape of plywood bends are in progress and some data have been obtained on the stability of shape of some bends when subjected to various atmospheric conditions. The results show that subsequent movements of set plywood bends are not appreciable unless they are subjected to high humidity conditions for a long period. Such treatment causes the bends to straighten out because of the increase of moisture; when re-dried, however, they do not return to their original shape.

Advisory Work in Seasoning and Bending

Close contact has been maintained with the trade and many visits have been received from kiln owners, kiln manufacturers and others interested in the seasoning or bending of timber. In addition forty visits have been made to firms. They have included several to a small furniture firm which, on advice received from the Laboratory, has installed a forced-draught electrically-heated drying room for the conditioning to a suitable moisture content of timber purchased in an air seasoned condition.

The number of enquiries dealt with during 1955 in Seasoning and Bending was 936.

TIMBER MECHANICS

Testing of Timber for Comparison of Species

The testing of timber for the comparison of species has continued during the year, and full strength data are available for further consignments of home-grown softwoods. The species tested include western red cedar, western hemlock, grand fir, Corsican pine, lodgepole pine and Sitka spruce. Data are now also available for dahoma and muchenche from Uganda and for African mahogany, tests of which have been completed during the year. Consignments of sepetir from Sarawak and pitch pine from Nicaragua have been tested. Limited tests have also been made on small consignments of bulletwood, roble, brush box, blue gum and Brazil wood. Tests are in progress on African padauk, muhuhu and home-grown rauli.

Strength data for routine testing are primarily for the comparison of species and for an assessment of their utilization value. When determined from tests using the 2-in. specimens made at many research establishments in accordance with internationally accepted standards such data are directly comparable. Data from tests with the 2-cm size specimen, which is now being used at the Laboratory to an appreciable extent for the testing of small-diameter trees are, however, not directly comparable in all properties with those from the larger 2-in. specimen and it has been necessary to establish the relationship between the data obtained from the two scales of testing. Investigations to this end have been completed and factors established for the conversion of results using the 2-cm size specimen to the equivalent values for the larger 2-in. specimen. A report on this work has been prepared[7].

The increased use of the small 2-cm test pieces in routine testing has also required standization of test methods and procedure. The techniques applicable to this size of test piece are described in a recent publication[8], which also includes strength data for those species of hardwoods and softwoods tested over the last few years.

Structural Use of Timber

The grading and testing for strength in structural sizes of home-grown softwoods have continued. Consignments of western hemlock, noble fir and Douglas fir from Dunster in Somerset, noble fir and Douglas fir from Novar Estate and Culloden respectively, and western red cedar from Alice Holt have been supplied by the Forestry Commission during the year.

The noble fir from Dunster was over twenty per cent stronger than that from Novar, somewhat higher than expected from their densities and the strength of the clear timber. This difference was not so apparent in the stiffness of the joists and it can be ascribed to the relative proportions of the defects present in the two consignments. Douglas fir showed a difference of only ten per cent between the two sites. This is reflected in the respective densities although in the clear timber the difference is somewhat less. The western red cedar was of similar density and strength to the Sitka spruce from Devon tested previously but was considerably less stiff; the stiffness of the red cedar joists was very low for their densities. The western hemlock joists were appreciably more dense and stiffer than the cedar ones but had only about the same bending strength, owing mainly to the relatively small knots in the latter species.

The strength of timber in structural sizes is closely related to quality. It is materially affected by defects such as knots and slope of grain, as well as density. The economic utilization for structural purposes of the rapidly increasing output of timber from softwood plantations in Great Britain will thus be linked closely to grading rules that take into account most of the characteristics affecting the quality. Such rules have now been recommended by an *ad hoc* Committee convened by the Laboratory. The Committee, representative of the Forestry Commission, the important softwood users, the Royal Institute of British Architects and the Timber Development Association, has formulated recommended grading rules for Sawn British Softwoods, and a leaflet describing these has been published[9].

Working stresses for the various species are an essential corollary of these grading rules and a scheme is now being prepared for the development of these stresses for the relevant grades of timber, taking into account the natural variation of the material.

Long-term Loading

The long-term loading experiments on the small glued trusses and on the 2-in. square Baltic redwood and Douglas fir beams started in 1952 have continued. Relatively large movements in the first few months under load were recorded in both experiments but in the last year increases in deflection, although continuing, have been much smaller. After one year under load some test specimens of both Baltic redwood and Douglas fir were unloaded and after conditioning were tested to destruction. No significant loss of strength compared with that of the original control was found but an increase in deflection over the initial deflection under the load of about 60 per cent in the Baltic redwood and 25 per cent in the Douglas fir was recorded. The beams of both species carried the same load, which was, however, a greater percentage of the ultimate strength of the redwood than that of the Douglas fir. The permanent set on removal of the load amounted approximately to the creep which had taken place during the year under load. During conditioning both species recovered about one-half of the respective permanent sets.

Strength of Struts

A report[10] has been published on the investigation on struts mentioned in the Report for 1954[11].

An investigation has now been begun to determine the most suitable formula to represent the strength of timber struts subjected to combined compressive and bending load, and tests are being made on struts covering a wide range of slenderness ratios for varying proportions of the two types of loading.

Strength of Timber Joints

Tests have been completed on three-member joints of European redwood made with $1\frac{3}{4}$-in. square toothed-plate timber connectors. The strength of the joints in tension parallel to the grain, compression parallel to the grain and compression perpendicular to the grain was determined.

Strength of Nailed Joints

The investigation begun in 1954 to examine the relationships between density

and the properties of stiffness and strength in nailed joints has now been completed.

The variation in the stiffness and the strength of both two-member (nails in single shear) and three-member (nails in double shear) joints with the two variables specific gravity and nail diameter has been examined in detail on the basis of the loads required to cause slips of 0·006 and 0·030 in. in the joints. The analysis of the results shows that the correlation coefficients between these loads and the specific gravity vary appreciably. Most of the coefficients that are greater than 0·60, however, show a reasonably close relationship between the stiffness and the strength of the joints and the specific gravity of the wood of the joint members.

The results of the tests also indicate that a relationship of the form $P=Kd^n$ exists between the stiffness and strength of the joints and the diameter of the nail, where P is the load, d is the nail diameter and K and n are constants. The constants K for both types of joint are approximately proportional to the specific gravity of the wood used and the relationship between joint stiffness and strength and nail diameter can be indicated by $P=kGd^n$, where k is a constant and G is the specific gravity of the wood. A report on the work has been published[12].

An investigation to study the effects of pre-drilling and clenching on the stiffness and strength of nailed joints of European redwood members has also been completed. Two-member and three-member joints of parallel members were tested in compression parallel to the grain for this investigation. The effects of pre-drilling were examined by driving the nails in some joints without pre-drilling and in others into pre-drilled holes of $\frac{5}{64}$ in., $\frac{1}{8}$ in., or $\frac{5}{32}$ in., which correspond to just under 50, 80 and 100 per cent respectively of the diameter of the No. 8 gauge nails used. The effect of clenching was examined by making the joints, the total thickness of the members of which was 3 in., with nails either 3 in. or $3\frac{1}{2}$ in. long, the protruding $\frac{1}{2}$ in. of the latter being clenched. In addition the effect of the direction of clenching was examined by clenching the nails in some joints perpendicular to the grain and in others parallel to the grain, in the latter case either in the same direction or in the opposite direction to the load on the member against which the nails were clenched.

The results show that for joints of parallel members made with No. 8 gauge nails, the diameter of pre-drilled hole which gives the greatest all round increase in stiffness and in strength is $\frac{5}{64}$ in.; this is also the amount by which the diameter of the hole is less than the diameter of these nails. It would appear that to obtain the most efficient joints of members of similar quality wood with other gauges of nail the diameter of the pre-drilled hole should always be $\frac{5}{64}$ in. less than that of the nail. A report of these investigations on pre-drilling and clenching is being prepared for publication.

Strength of Glued Joints

The use of synthetic resin glues as a means of connecting members is gaining favour in timber construction and a programme of strength tests on glued joints of members of structural size has therefore been put in hand. Exploratory tests have shown, however, that there is difficulty in the testing of glued joints. When they are under load initial failure may occur in the wood of the members, with distortion of the test-piece, before the joints can be stressed sufficiently to cause shear failure in the glue lines or in the wood close to the glue lines. With three-member joints the glue can be stressed up to 1000 Lb/sq. in. when the load is

applied parallel to the grain of the members, but when the load is applied at right angles to the grain failure occurs at a much lower value of stress. Work on these points is continuing.

Strength of Plywood

General.—The standard testing of $\frac{3}{16}$-in. 3-ply has continued and ultimate strength values for five species, adwea, abura, obeche, landosan and muchenche have been determined. Data have now been obtained under this project for thirty-six different wood species.

At the request of a plywood manufacturer the standard testing procedure was used to determine the strength properties of two samples of seraya plywood. The samples, which were identified as red seraya (*Shorea* spp.) and white seraya (*Parashorea plicata*), showed no significant difference in strength and density. A comparison between these results and others previously obtained for a second consignment of white seraya, however, showed considerable difference, the earlier tests giving much higher strength and density values. Where strength is of importance care must therefore be taken to distinguish between high and low density material or, if this is impossible, then for the general run of seraya plywood which may include a number of species, the average strength for the low density material (red seraya) should be used.

Effect of Adhesive on Strength.—To study the effect of the adhesive on the strength properties of plywood, tests were made on panels of gaboon. The panels were constructed using veneers of different thickness and three types of adhesive.

The results of the tests are of considerable interest. Strength is apparently affected by two factors, one the permanent compression of the wood during bonding and the other the formation of thin layers of a composition of wood and adhesive. The influence of these factors, which generally results in greater strength, increases with a reduction in the veneer thickness and is greater for a phenolic than for a urea resin. Too many variables such as species, surface characteristics, density, time in press, temperature and moisture content are present to make it possible to relate these factors more closely to strength. The investigation indicates, however, that if the procedures recommended in previous reports[13] for plywood of ordinary dimensions are applied for calculating the strength of plywood made from thin veneers, $\frac{1}{50}$ in. thick, errors of up to 30 per cent may occur between calculated and actual strength values. A detailed report of the investigation is being prepared for publication.

Variability of Plywood.—Data on the variation in strength properties are required for one stage in the determination of working-stress values. Previous investigations have necessarily used plywood made at the Laboratory under controlled conditions and the results cannot, without direct experimental evidence, be used to give a measure of the variation which will occur with commercial products. Tests have consequently been started on batches of $\frac{1}{2}$-in. and $\frac{3}{16}$-in. gaboon plywood obtained from various manufacturers with the object of determining this variability and comparing the results with those previously obtained for the laboratory-made plywoods.

Plywood for Concrete Formwork

Considerable quantities of plywood are used in concrete formwork, for which it possesses the advantages of light weight, high strength and good service life.

Although design charts were available for Douglas fir plywood similar data were lacking for the many other species of plywoods now being manufactured. A study was made of design methods, and general solutions to the design equations for concrete forms were determined and presented in the form of graphs. An article[14] has been published giving the results of this work. It indicates the methods of applying the general solutions to plywoods of any thickness, species or construction. Practical points regarding preparation, erection, dismantling and storage of plywood formwork are also considered.

Laminated Timber Construction

Two-species Laminated Beams.—A report on the work which led to the derivation of a basic theory of design for two-species laminated beams has now been published[15]. It was recently reported that this method of construction, which consists of gluing relatively thin layers of a strong dense species of wood to a core of a lighter weaker species, has been used in America for the production of ladders and considerable advantages in strength and performance were claimed over those constructed from solid timber. Because of the interest being shown and the requests for information a short article describing the method was published[16].

Laminated Versus Solid Timber Beams.—From enquiries received, some doubt seems to exist as to the actual advantages that can be obtained from laminated construction. The question is frequently asked "Are laminated beams stronger than solid ones?" A series of tests has been carried out on solid and laminated beams to provide a practical answer to this question. The results of these tests are summarized as follows:

(a) Laminating itself imparts no fundamental increase in strength.

(b) Laminated beams are no stronger than solid ones when both are made from material free from defects and are at the same moisture content throughout.

(c) When material containing defects such as knots and irregular grain is used a laminated beam in which care is taken to arrange the laminations will have greater strength than a corresponding solid one.

(d) Vertical laminating permits a higher design stress to be used than for solid members and this in practice means greater strength.

(e) Laminated curved members are both stronger and stiffer than steam-bent solid ones.

An article describing this work and the results obtained has been published[17].

Laminated Timber Arch Design.—Assistance was rendered to a timber constructional company, working in co-operation with a firm of timber merchants, in a project involving the design of laminated timber arches. Prototypes of two arches, one a circular arch of 40-ft span and the other a 30-ft parabolic type of arch were constructed and supplied for test. Both arches were made from Baltic redwood of average quality bonded with a cold-setting urea-formaldehyde resin.

The tests were carried out in accordance with Codes of Practice procedure for the testing of prototype structures, using the system of loading developed by the Laboratory. This system, which is adaptable to all types of structural unit, applies the distributed loading required to equal points over the arches through

a system of pulleys and a continuous wire rope. The rope is continuous on both sides of the arch and is subjected to tension by means of a winch at each end. The reactions at the ends are measured by means of pressure gauges connected to hydraulic capsules mounted under each end of the truss.

Both arches performed satisfactorily under test. The test on the 40-ft span circular arch is illustrated in Plate 4.

An investigation has been started to examine current methods of designing arches with a view to establishing design procedure applicable to laminated timber constructions. An inclined portal arch with a span of 30 ft and a ridge height of 16 ft is being constructed and on completion will be subjected to a series of tests.

Effect of Temperature on the Strength of Timber

The investigation to determine the effect of kiln drying by superheated steam on the strength properties of timber, referred to in the Report for 1954 (p. 16), has now been completed and a report published[18]. The results of the tests, which were made on four different species, abura, obeche, Scots pine and African mahogany have shown that for the particular kilning times and temperatures involved the accelerated drying of the first three species had no appreciable adverse effect on the static and impact bending strength properties. With the mahogany, however, where the high temperature treatments were more severe in relation to the normal drying schedule, the strength properties have been affected to a greater extent, and there is an appreciable reduction in the toughness of the wood and in its ability to resist suddenly applied loads. This reduction is reflected in increased brittleness of the material.

Effect of Depth on the Strength Properties of Timber Beams

The tests started last year to examine the effect of varying depth on the strength and elastic properties of beams have been completed and a report has been prepared. A series of beams, 2 cm. in width and covering a depth range from 8 cm to $\frac{1}{2}$ cm, were tested.

The results show that by far the greater proportion of any effect of depth in timber beams occurs when the material is stressed beyond the limit of proportionality. There is an appreciable decrease in the maximum bending strength of up to 15 per cent when the depth of the beam is increased from 2 cm to 8 cm. Fibre stress at the limit of proportionality is very much less affected over the same range of increase in beam depth.

A study of the strains in the extreme tension and compression fibres and of the maximum tensile strain on the beams was made using wire-resistance strain gauges. An increase in the depth of the beam resulted in a marked decrease in the maximum strain in the fibres under tension but the decrease in strain at the proportional limit over the same depth range was appreciably less marked. A point of interest arising from the tests was that within the elastic range for beams of all depths no significant difference was observed in the strains developed in the extreme tension and compression fibres. The modulus of elasticity was found to be virtually the same for the beams of all depths.

A series of supplementary tests to investigate the strain distribution across the depth of a beam is now in progress.

Abrasion

Standard abrasion tests on *Ficalhoa laurifolia* have been completed. This hardwood possesses high wearing qualities and its behaviour, which is very similar to that of hardwoods of the birch or beech class, suggests that it should be suitable as flooring for all conditions of pedestrian traffic.

Standard tests on African padauk to assess its suitability for flooring are in progress.

Miscellaneous

A number of *ad hoc* investigations have again been carried out at the request of manufacturers and Government departments. They include tests on four box purlins for use in housing, and further tests on poles of British Guiana wallaba for electric transmission lines for the Central Electricity Authority. These were poles which included the sapwood, and they were tested to compare their ultimate strength with "de-sapped" wallaba poles previously tested and referred to in the Report for 1954 (p. 16). *Eucalyptus paniculata* telegraph poles from Natal were tested for a comparison with *Eucalyptus saligna* poles from the same source. Three species of *Eucalyptus* poles, *E. microcorys*, *E. saligna* and *E. paniculata*, have also been tested for the Kenya Forest Department to provide basic data on the species grown in the Colony. A report on the investigation has been submitted to the Forest Department.

A series of tests has been made to compare the axial withdrawal strength of standard wood screws, two types of drive screw and one type of screw nail in five species of wood.

Advisory Work in Timber Mechanics

A total of 352 enquiries concerned with miscellaneous aspects of the strength of timber and plywood have been dealt with during the year. The Laboratory has continued to advise, *inter alia*, government departments and the Timber Development Association on many matters concerned with the structural use of timber and with the utilization of hardwoods for flooring. Assistance has also been given to the British Standards Institution in connexion with the preparation and revision of standards for gymnastic apparatus, scaffolding boards, wood blocks for floors, and methods of tests of small clear specimens of timber.

WOODWORKING

Planing Investigations

The chief subject of research during the year has been the planing of wood and it has been approached from various aspects. The cutting action in planing normally consists of the periodic removal of thin horn-shaped chips as the wood is fed past rotating cutters. The cutting edges are engaged with the wood for only small portions of each complete revolution and not only is the depth of penetration increasing from zero at entry to a maximum at the cutter exit, but also the direction of cutting changes relative to the grain. It is thus exceedingly difficult to observe the actual behaviour of the wood during the cut and to measure the transient forces exerted by each cutter. The use of a stroboscope permits the formation of successive chips to be seen at any specific point on the cutterpath, when the speed of flashing corresponds to that of the rotating cutter. A general indication of the action during a single engagement is also obtained when the

flashing rate is made slightly less than the speed of rotation. Additional knowledge is gained by taking series of photographs with the aid of electronic flash equipment, which gives high intensity illumination of very short duration (5 μsec). In order to build up a true picture of what happens in rotary cutting, however, it has been found necessary to investigate rectilinear cutting carried out at various directions to the grain. The chip so produced is usually of uniform character and is shorter and slightly thicker than the actual portion of wood removed from the test specimen. This change in the dimensions varies according to cutting angle, depth of cut and grain direction. Data on these were obtained from a series of tests made with special apparatus operated at relatively slow speeds of cutting. In addition, photographs at low magnification have been taken which give details of the deformation and failure of the wood at and near the cutting edge. This study has been extended to cover high-speed rectilinear cutting and a prototype machine has been constructed for the work. It differs in principle from the slow-speed machine in that the wood travels past a stationary cutter, instead of the latter being moved. The cutter holder has the necessary means for adjustment of cutting angle and depth of cut, and in the final design it will have force-measuring devices. Preliminary tests have provided further information about the failure of the wood near the cutting edge and the varying relationship of the chip dimensions to the original length and depth of cut under the different conditions. A typical photograph of chip formation is shown in Plate 5.

Information has not hitherto been available about the frictional resistance to feed movement offered by wood in sawing and machining. An investigation into this was therefore begun and preliminary tests have been made on an experimental surface planer having front and back tables each 6 ft in length. This machine has provision for changing the cutting angle and the spindle speed, and also a feeding attachment giving speeds of 20 to 120 ft/min, consisting of a grooved drum driven through variable-speed and worm-reduction gears by a separate motor. A cable is wound on the drum and connected to a cantilever beam dynamometer on the test-specimen holder. The varying deflection of the beam under the pull of the cable is measured electrically by means of an inductive transducer, bridge, amplifier and recording unit. With this apparatus eight different timbers were tested over a range of nine feed speeds and three cutting angles. The average tangential force at the cutters was calculated from the net power required in cutting. The difference between the feed resistance and this tangential force thus gave the frictional resistance during cutting. It was found that the friction between the moving wood and the machine table was in general greatest with the newly machined surface (at the back table), slightly less during cutting (owing to the effect of vibration) and least at the front table, owing to the small smoothing action at the end of the previous cut. The eight timbers showed considerable difference in their behaviour, but with all of them the coefficient of friction increased with the speed of feeding.

Tests were also carried out on this machine to obtain further information on the influence of the feed speed on the net power demand in planing. Six different species of timber were planed at a cutting angle of 30°, with the feed speed ranging from 20 to 60 ft/min. The relationship between the power (P) and the feed speed (f) appeared to be linear over the range tested and conformed to the equation $P=A+Bf$, where A and B were cutting constants. When the energy consumption per unit area cut was calculated and plotted, it was seen that the cutting

energy decreased as the rate of feeding was increased, so that the operation became more efficient. The ratio of density to net power demand appeared to be fairly constant for any one species but not between species, probably owing to the greater influence of other factors.

Investigation of the blunting of planer cutters was continued, and a full report on work to date is being published[19]. Information on the influence of the sharpness angle on the nature and amount of wear of the cutting edge has been obtained. In general, there is far less tendency for the edge to fracture, and wear is slower, with the larger values of this angle. A convenient method of assessing

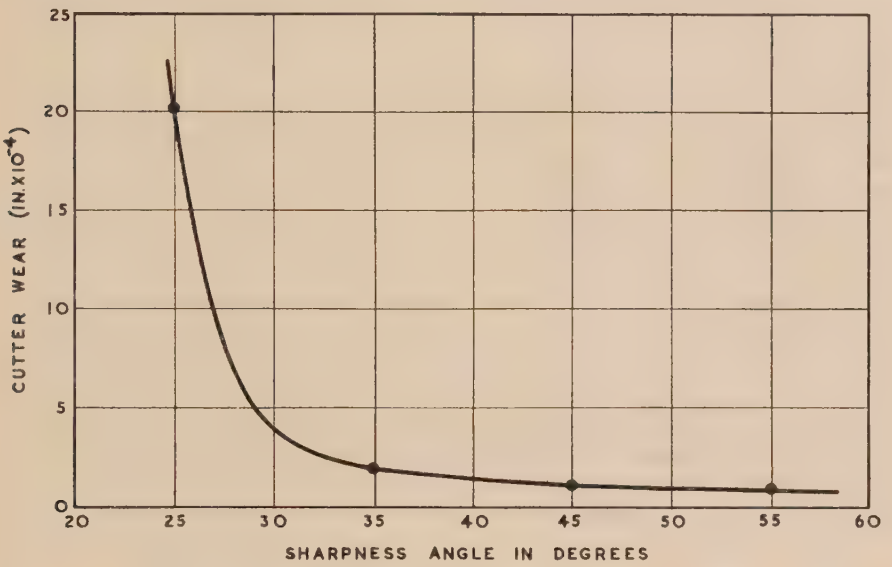


FIG. 1. Relation of sharpness angle to wear of cutter

wear is to measure the average recession of the edge throughout the length of the engaged portion of the cutter. This is easier and more accurate than estimating the volumetric wear, particularly if the edge has failed chiefly by fracture. In comparing the wear of cutting edges of different types, this criterion gives also a direct indication of the class of finish that they will produce on the wood. The results of a series of tests on high-speed steel cutters are shown in Fig. 1 and in Plate 6. They are based on the wear sustained by cutters with various sharpness angles in planing equal runs of beech under the same conditions of spindle and feed speeds, cutting angle and depth of cut. It will be noted that the blunting increased slowly as the angle was reduced from 55° to 35° but then rapidly with further reduction to 25°. Edges having this last value of sharpness angle were weak and the effect of the fractures was visible on the wood surface after only 100 ft of stock had been planed. An angle of 35° is most commonly used in practice but from the curve it appears to be almost at the transition point between cutters capable of giving good service and those having weak edges liable to fracture and to blunt quickly. A reduction of 2° or 3° in this angle, as might occur in commercial sharpening, could result in considerable lowering of the cutter performance and be the cause of rapid blunting otherwise inexplicable.

Confirmation of this idea, that 35° is not quite suitable for practical use, is often provided by the behaviour of cutters on hand-feed surfacing machines. When freshly ground and honed, their edge life is noticeably shorter than that obtained after they have been re-sharpened by honing on the block, when their sharpness angle is automatically made slightly greater than the original 35°, owing to the position imposed on the hone by the shape of the cutterblock.

A limited test was also carried out to study the influence of cutting angle on the edge-life of cutters. It was found that a change in the angle of from 30° to 15° resulted in an increase of about 60 per cent in the amount of wear of edges having a sharpness angle of 35°, but had no effect on a 55° edge. Observations made during the test indicated that the wear suffered by cutters with the smaller sharpness angle was caused by fairly extensive breaking away of the edge during the early part of its life.

The performance of cutters tipped with a cobalt-chrome-tungsten alloy and with tungsten carbide was also studied in the planing of beech, makoré and plywood. Table 1 shows typical results obtained thereon in comparison with those on high-speed steel. In addition, four special alloys used for hard-tipping in the engineering industries were tested. Two of these were alloys in the boronised nickel-chrome group and two had a base of chromium and iron with other constituents. Low voltage welding equipment, having a carbon electrode as the heating element, was used to apply the material to small planing cutters, and some difficulty was experienced in obtaining homogeneous deposits and freedom from cracking. The deposited material was also somewhat troublesome to grind, the two hardest alloys requiring the use of a diamond-dust-impregnated wheel. Their edges tended to fracture in cutting, even with a 55° sharpness angle, and no superiority to the cobalt-chrome-tungsten alloy previously tested was shown. The other two alloys provided fairly clean cutting edges, but their performance was only slightly better than that of high-speed steel in cutting plywood.

TABLE 1

Performance of H.S. Steel, Cobalt-chrome-tungsten alloy and Tungsten Carbide Cutting Edges.

	Makoré		Plywood		Plywood	
	Sharpness angle 55°		Sharpness angle 35°		Sharpness angle 55°	
	Output (lin. ft)	Edge wear (10^{-4} in.)	Output (lin. ft)	Edge wear (10^{-4} in.)	Output (lin. ft)	Edge wear (10^{-4} in.)
High-speed Steel	480	12	63	83	63	69
Cobalt-chrome-tungsten alloy	1 800	12	126	93	126	67
Tungsten carbide	25 000	12	2 016	53	7 000	63

Wood Boring

A report[20] has been published of the studies made to date of the machine-boring of wood. It contains details of the equipment used and methods of testing,

with information on the behaviour of various woods. Descriptions and results are given of a series of investigations to find the relationship of feed speed, spindle speed and tool size and shape to the power demand and the quality of the finish. The proportional sharing of the work done in cutting by the various parts of the bit is also studied.

General

Other experimental work in sawing and machining has included: the preparation and testing of two circular saws, one with standard teeth and the other with a special form of tooth designed for smooth cutting, all other features being identical; tests on the resistance to cutting of pencil cedar; the design and construction of apparatus for stress analysis in wood cutting; minor tests on the machining of "Perspex"; power measurement and observation of machine finish in producing flooring, matching, siding and square-edged stock from ten different species of home-grown softwood.

Full-scale standard tests have been carried out to determine the working and nailing properties of the following species:

Corsican pine, kiln dried, from the Forestry Commission, Bere Forest
Western hemlock, kiln dried, from the Forestry Commission, Bere Forest
Western red cedar, kiln dried, from the Forestry Commission, Bere Forest
Douglas fir, kiln dried, from the Forestry Commission, Dunster Forest
Douglas fir, kiln dried, from the Forestry Commission, Culloden Forest
Grand fir, kiln dried, from the Forestry Commission, Novar Estate, Scotland
Grand fir, kiln dried, from the Forestry Commission, Dunster Forest
Lodgepole pine, kiln dried, from the Forestry Commission, Inverness-shire
Sitka spruce, kiln dried, from the Forestry Commission, Roxburgh, Scotland
Roble, air dried, from the Forestry Commission, Bedgebury Forest
Sepetir, kiln dried, Sarawak
Dahoma, kiln dried, Uganda
Muchenche, kiln dried, Uganda
Andaman bulletwood, kiln dried, Andaman Islands

Advisory Work in Woodworking

Advice has been sought on methods of improving efficiency in sawing and machine operations, the design of tools for special purposes, the working properties of different timbers and on many other matters in sawmilling and woodworking. The design of furnaces for waste disposal and for steam generation, the manufacture of fuel briquettes, the construction and operation of charcoal kilns, and the utilization of sawdust and wood chips have also been the subjects of enquiry. Technical enquiries amounted to 162 during the year, and visitors to the section requiring information numbered 62.

COMPOSITE WOOD

Properties of Adhesives

In the older series of long-term durability tests on glues, several experiments are approaching the end of their prescribed periods. One, dealing with adhesives for plywood has already completed its five years' exposure in Nigeria and a report has been published[21]. In this experiment, beech and gaboon plywood made with various adhesives was exposed in two environments in England

and in two at the Ministry of Supply's Tropical Testing Establishment at Port Harcourt in the coastal belt of Nigeria. In England the test plywood was stored in a normally heated workshop and on vertical racks facing south in an open field. In Nigeria the test material was stored in an open-sided bush hut and also attached to nearly horizontal racks facing south in an open compound. The adhesives under test were of the phenol-, resorcinol-, melamine- and fortified and normal urea-formaldehyde types and the test plywood was without the protection of paints or other protective coating. After five years' storage under the interior conditions in England the deterioration of all glues was without practical significance. In the outside exposures the phenol and resorcinol glues showed negligible degrade; the performance of the melamine, and the fortified and normal ureas is shown for each species, in each environment, in Table 2.

TABLE 2

Type of adhesive	Exposure					
	England		Nigeria			
	In open field		Under open-sided hut		In open compound	
	Beech	Gaboon	Beech	Gaboon	Beech	Gaboon
Melamine-formaldehyde	Fail (4)	S1.D.	M.D.	M.D.	Fail (2)	Fail (3)
Fortified urea-formaldehyde	Fail (4)	M.D.	M.D.	S1.D.	Fail (2)	Fail (4)
Urea-formaldehyde	Fail (2)	M.D.	M.D.	M.D.	Fail (1½)	Fail (2)

S1.D.=Slight deterioration in the quality of the glue bond.
M.D.=Marked degrade in the quality of the glue bond.
Fail (X)=Failure as defined for this experiment in (X) years.

Last year's report[22] referred to new durability experiments that would incorporate not only the modern glues in current use, but also some of those still in the developmental or experimental stages. A comprehensive selection has been made, with the collaboration of the adhesive makers, and the necessary plywood and assembly joints have been prepared. Initial testing has been completed, and the material placed in various environments. Plate 7 shows the site in which samples are fully exposed to the weather. The systematic study of paints and similar surface coatings as such is not within the Laboratory's programme but the influence of a limited number of standard finishes on the life of the glued products is being investigated.

Resin glues of the polyvinyl acetate (P.V.A.) type have attracted considerable interest in the furniture industry. In collaboration with the British Plastics Federation, the Laboratory has investigated standard methods of testing such adhesives and has developed what appears to be a suitable method of assessing their resistance to sustained loading. At the time of this work, the proprietary glues available were still in the developmental stage, and it would therefore be premature to give specific results and apply them to the type as a whole, but it can be said that the question of "sustained load" is one requiring the closest attention of manufacturers and users of P.V.A. adhesives.

Work on the gluing of laminated members under different conditions and on the bonding of preservative-treated wood continues. With the latter, the experiments mentioned in the Report for 1954[23] have been extended to include more species and brands of glue. Comparison is being made between similar sets of samples exposed to weather and subjected to a repetitive drying and wetting cycle, respectively.

Considerable time has been spent in rationalizing the knife-test method of assessing the bond quality in plywood. The basis of the assessment is the appearance of any veneer in a board when the one above has been removed in a definable manner by means of a specially shaped knife. The highest bond quality obtains when the plies separate entirely through breakage of the wood, and the glue line remains covered by adhering fibre; the lowest quality of bond is shown when the upper veneer parts by separation along the glue line with few or no wood fibres left adhering. Between these extremes is an infinite number of gradations, and from a large number of knifed test-pieces, it was found possible to select samples which, when arranged side by side, showed a smoothly graded decrease in wood breakage from the maximum to zero, i.e. which present bond quality in a visual-linear scale. From such a set, pieces were taken from the extremes and at regular intervals to provide a Master Scale, the highest bond quality being numbered 10, the lowest 0, with intermediates of 8, 6, 4 and 2. Such a scale is shown by Plate 8. By visually comparing a knifed sample with those of this set, the glue line can have assigned to it a number that relates its bond quality to an absolute scale of values; interpolation between the even numbers of the scale is also practicable. This new method of assessing knife-test results has been offered to the British Standards Institution for inclusion in certain plywood specifications now under revision.

It should be noted that knife-testing is basically a qualitative method of assessing bond quality as distinct from the quantitative measurements given by the traditional mechanical tests. No simple correlation between the two appears to exist, and the relative merits of the two tests are not as yet established. Discussions upon this important matter, covering both plywood and assembly work applications are taking place with other Forest Products Laboratories.

Study of Temperature Penetration Rates in the Manufacture of Plywood

During the manufacture of plywood the veneers spread with glue are bonded under heat and pressure in a hydraulic press. The heat necessary to cure the adhesive is supplied by the platens and has to penetrate through the wood to the innermost glue line. The rate at which the heat is conducted through the wood has been considered by many investigators and solutions of the equation of heat conduction have been calculated. The application of the theory to the manufacture of 5 ft square plywood has been the subject of an extensive investigation at the Laboratory. Since the preliminary experiment reported in the Report for 1953[24], the work has been extended and the heating curves for $\frac{1}{2}$ in. thick plywood of four species at various moisture contents have been determined for two commonly employed pressing temperatures. An analysis of the results showed that at a pressing temperature of 95° C (203° F) it was possible to calculate, from the equation of heat conduction, the heating times for the innermost glue line of plywood but only with very low accuracy, e.g. if the board was composed of veneers initially of between 6 and 10 per cent moisture content and weighing between 25 and 40 lb/cu. ft, the measured heating times were within the limits

of –15 per cent and + 5 per cent of the calculated times. Outside these limits of moisture content and weight, the heating times were subject to even wider limits of certainty. A similar order of accuracy was obtained at the centre of boards made at pressing temperatures of 115° C (239° F) but at the edge the temperature of the innermost glue line was, at the end of the pressing cycle, still below that at the centre. The extent of this temperature gradient was influenced by the moisture content of the veneers being pressed. With initial moisture contents of 17 per cent the edge of the board was as much as 15° C (27° F) below platen temperature at the end of the pressing cycle and the gradient became negligible only when the initial moisture content of the veneers was under 2 per cent, a level rarely reached in commercial manufacture.

Although the platen temperature of 115° C (239° F) was never attained at the edge of the test boards the glue bond was, however, satisfactory. The reason for obtaining this cure at temperatures below that recommended is being discussed with the glue manufacturers.

Although a knowledge of the rate of temperature penetration contributes to obtaining the optimum pressing schedule, it should be remembered that the object of applying heat is only to effect the cure of the adhesive, and that the attainment of the required glue line temperature is but one of the many factors which contribute to the quality of the product.

Radio Frequency Studies

In 1951 the work of curing adhesives by radio frequency heating had to be discontinued because of shortage of staff. Recently, however, it has been possible to restart this work and the present series of experiments is concerned with the application of this type of heating to the cure of the adhesive in jig-assembled joints. A universal wooden press has been constructed and electrodes incorporated for the gluing of a 6 ft-long batten to plywood. The most satisfactory electrode arrangements are being determined and the phenomenon of standing waves in long electrodes and their effect on the heating rate is being investigated. Arcing is one of the commonest troubles with this type of heating and its cause is being studied. The present series of experiments indicates that arcing results mainly from bad jig design and occurs with electrodes which have been fouled by the glue squeezed from the joints being cured.

Moisture Content Determination

At a meeting of the Laboratory's Plywood Research Panel the feasibility was considered of using radioactive isotopes for moisture content measurement in veneers. The Isotope Division of the Atomic Energy Research Establishment at Harwell was approached and a method was evolved which would give a continuous record of the moisture content of veneers passing through a neutron beam. This would record the amount of hydrogen in the wet veneer and hence, indirectly, the amount of water. Wood substance, itself, however, contains a significant and variable quantity of hydrogen; this would be a probable source of error. The moisture content reading obtained from the instrument would also be influenced by the mass of wood within the neutron beam, i.e. by the density and thickness of the veneer. The density of wood of any one species can vary considerably and thickness variations of the order of ± 3 per cent are common. It was therefore concluded that the proposed method of moisture determination

using radioactive isotopes would be no more satisfactory than existing electrical methods.

Trials of Timber for Plywood Manufacture

Special tests on the suitability of adwea for aircraft plywood showed that the species is not a good substitute for Canadian birch. Trials of timbers for commercial plywood have been made on dahoma, muchenche, abura and aningueria from Uganda. Tests on home-grown Scots pine have been repeated, mainly to investigate gluing problems that arose in some preliminary trials.

At the request of industry, a small investigation into "shelly" gaboon was made. Shelliness manifests itself as a form of blister in the finished plywood, and is characterised by rupture within the veneer itself rather than by separation at a glue line. Only one log of gaboon was available that was believed to be of a shelly nature, and on this limited material, the tests showed that:

1. The presence of veneer likely to blister could not be detected by eye in either the green or the dried state.
2. When pressed at 145° C and at a moisture content of 12 per cent, only veneers from the inner parts of the log gave blistered plywood.
3. Even "potentially blisterable" veneer gave no trouble if the moisture content was below 8 per cent at the time of pressing.
4. There were slight indications that the shelly veneer was associated with the presence of brittle heart.

General

The Adhesive Makers' Panel has completed its tenth year of service, and at the request of its industrial members now includes representatives of the Admiralty, the Furniture Development Council and the Adhesive Manufacturers' Association. To the members of this informal panel, and of its sister panel—the Plywood Research Panel, the thanks of the Laboratory are again due for their unstinted service during the year.

Advisory Work in Composite Wood

During the year 465 enquiries were received.

WOOD PRESERVATION

Testing of Wood Preservatives

In 1950 a new field service test was started to determine how the effectiveness of a preservative varies with its concentration in the wood. Most of the modern water-soluble type preservatives are now under test and the two later grades of Boliden, namely S.25 and K.33, have been added during the year.

The possibility of assessing and comparing creosotes by this form of test is being examined. Coal tar creosote is known from practical experience to be a highly effective preservative but there is not a great deal known of how its performance varies with its concentration in the treated zone of the wood. Since the introduction early this century of the Rueping process, in which excess creosote is removed during treatment, there has been a tendency to use very low retentions, sometimes to the point of impairing the efficiency of the treatment. Some experimental data relating performance to the creosote concentration in the

timber would be very useful in showing the necessity of fixing minimum net retentions in a rational way, i.e. according to the life required, and not by initial cost or convenience of treatment. The main problem in testing creosote by this scheme is to find a satisfactory method of preparing specimens containing a wide range of concentrations of creosote and at the same time to ensure that the distribution is uniform. The most convenient method is to treat with graded concentrations of creosote in a volatile solvent and work is in progress to find a satisfactory solvent to use. The most promising appear to be benzene, toluene and xylene and an investigation is being made on their subsequent removal from the wood and on the distribution of the creosote. The results so far obtained indicate that with benzene, the most volatile of the solvents, a steep creosote concentration gradient is set up in the specimens both in the lateral and the longitudinal directions.

Sleeper Investigations

The experimental sleepers at Micheldever and Helmdon were removed and examined during the year and only those at Selling now remain. Examination of these sleepers did not result in any new findings but confirmed two important observations which had been made earlier at other sites. The results at Micheldever showed that decay of the underneath heartwood face, which is a common cause of sleeper failure in some districts, can be prevented entirely by modifying the creosote treatment so as to obtain a reasonably good depth of penetration on this face. After 20 years the sleepers at Helmdon were still in a very good condition. Their good performance supports the indications obtained from the other ex-L.N.E.R. site at Haddenham, namely, that the practice of laying sleepers heart face up may give a longer mechanical life than that of laying them heart face down.

During the year several parties of the civil engineering staff of British Railways visited the Laboratory and the results of these sleeper trials were discussed.

Among the miscellaneous sleepers which have been examined recently one batch was of particular interest. They came from a group which had been in service in a tunnel for 33 years and were still unaffected by decay. They were found to be creosoted Baltic redwood but an unusual feature of the creosoting treatment was that the heartwood, as well as the sapwood, was penetrated completely. The concentration of the creosote in the heartwood was much greater than that in the sapwood, approximately 10 lb/cu. ft compared with 2 lb/cu. ft yet measurements made on a specimen cut from a small untreated zone indicate that the wood is not abnormally permeable. A sample of the creosote has been extracted and is being examined by the Coal Tar Research Association.

Permeability of Timber

Measurements of the longitudinal permeability to air of about a hundred different species of wood have shown that it varies over a very wide range. Hardwoods appear to have a permeability range of about five million fold and softwoods about one tenth of this. In the upper part of this range there is evidence that with hardwoods permeability is primarily a function of pore size and number. In the medium and low part of the range, however, permeability is determined by the extent of pore blockage, e.g. by tyloses and gum deposits, and the relationship no longer holds. An interesting correlation has been found between the permeability of hardwoods and their durability, i.e. resistance to fungal decay. It appears that in general the permeable woods are perishable and impermeable ones are

durable. This relationship does not appear to hold for softwoods. A report on this work has been prepared.

Work is continuing on the permeability of the common softwoods in the longitudinal, radial and tangential directions.

Protection of Timber Against Weathering

A field service trial on a few of the cheaper methods of finishing external woodwork to prevent weathering and to help retain something of the initial appearance of the wood has been in progress for about a year. At present the results indicate that linseed oil is one of the best materials for this purpose. It appears to be nearly as effective when diluted sufficiently to apply by brush as when rubbed in neat in the traditional way.

Estimation of Creosote in Wood

Some work has been carried out on the estimation of residual creosote in treated wood by solvent extraction in order to assess the accuracy of this method. One known source of error is the removal of wood extractives with the creosote. It was found that another is the adsorption of the extracting solvent by the wood. Up to about two or three per cent of the weight of the wood may be adsorbed and retained after oven-drying. When the creosote content is based on the weight of wood before and after extraction a low result is obtained and this error can be large when estimating low residual creosote concentrations. In such cases there are indications that more accurate results can be obtained by evaporating off the solvent and weighing the creosote residue.

Advisory Work in Wood Preservation

The advisory work continues to be concerned mainly with the durability of timber under various conditions of exposure and the effectiveness of preservatives and of methods of treatment.

The number of enquiries received during the year was 425.

MYCOLOGY

Culture Collection

The collection of type cultures has been maintained in good condition by regular subculturing. A new refrigerator has been installed in which all cultures of moulds and staining fungi can be kept at about 10° C, thereby greatly reducing the risk of their becoming contaminated by mites. Fifty subcultures have been supplied to other research workers and to firms carrying out standard tests; 66 cultures have been submitted to the Laboratory for identification. Many of the cultures received from overseas territories cannot be matched with cultures already in the collection and their identification is possible only if they can be induced to fructify. A glass case in which a high humidity can be maintained has therefore been designed to contain cultures from which fructifications are desired. Detailed descriptions of the cultures of 12 more species have been prepared and transferred to perforated cards.

Soft Rot Investigations

Co-operation with the Central Electricity Authority on the problem of soft rot in cooling towers was continued during the year.

Soft rot has been observed in samples of Californian redwood and other timbers received from the United States and the Union of South Africa. In a series of samples from the latter it was noted that fungal attack had occurred only in samples from the base of the towers; the deterioration in samples from the centre and top of the towers, though similar in gross appearance to soft rot, appeared to have been caused by bacteria. These observations have offered some support to the view that the operating temperatures of cooling towers in the tropics and sub-tropics may be too high to permit fungal attack and that attack by bacteria may then assume greater importance.

Work on the chemical and physical changes brought about by the soft rot fungus *Chaetomium globosum* continues.

A long-term test to determine the extent to which *C. globosum* can attack beech samples freely exposed in air at high controlled atmospheric humidities has been started, and tests have also been set up to follow the incidence of soft rot in Scots pine and beech samples submerged in fresh water.

Tests of about twenty species of timber against *C. globosum* indicate that the resistance of hardwoods to attack by this fungus is, with a few exceptions, closely proportional to their resistance to attack by Basidiomycete fungi, very similar losses in weight being brought about in *small* test pieces. This is in marked contrast to the behaviour of coniferous woods, amongst which wood of low durability shows a high resistance to attack by *C. globosum*.

The role of the micro-fungi in the decomposition of wood has been described in a paper presented to the British Wood Preserving Association[25].

Laboratory Tests on Wood Preservatives

In addition to carrying out a series of standard wood block tests, time has been devoted to studying possible improvements in the technique of carrying out such tests. A British Standards Institution committee is undertaking revision of the standard method of test laid down in British Standard 838 and the Laboratory is co-operating in a series of comparative tests.

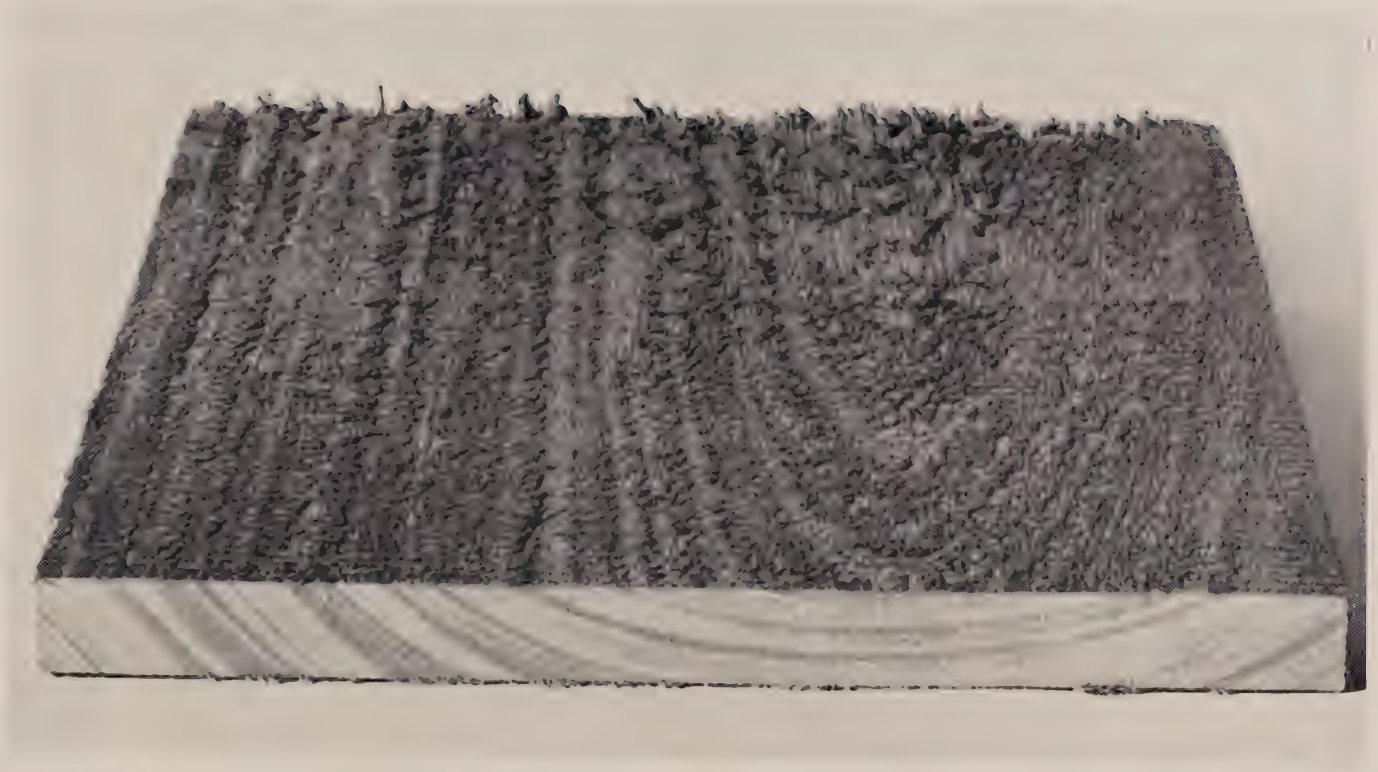
Standard block tests have been carried out on nine proprietary wood preservatives on behalf of their manufacturers. The toxicity of one of these to the soft rot fungus, *Chaetomium globosum*, was determined and the toxic limit was shown to be higher than that for Basidiomycetes.

The toxicity of pentachlorophenol to *C. globosum* has also been tested. Absorption of about 0·6 lb/cu. ft is required to prevent attack of beech veneers exposed to the fungus by Abrams' mycelial mat method. This contrasts with the absorption of only 0·08 lb/cu. ft required to prevent attack of beech exposed to *Polystictus versicolor* by the method described in B.S.S. 838. Ortho-phenyl phenol and its sodium salt were found to be toxic to wood-destroying fungi. A surface treatment with 0·01 per cent malachite green, a dyestuff frequently incorporated in preservatives, failed to prevent decay. A series of blocks dip-treated with a mixture of lauryl pentachlorophenol and pentachlorophenol has been exposed to fungal attack and a second duplicate series is weathering in the open for one year before the mycological test.

Comparative tests of a creosote against two strains of *Lentinus lepideus* using soil/block (Leutritz) and the agar/block (Kollé flask) methods showed that

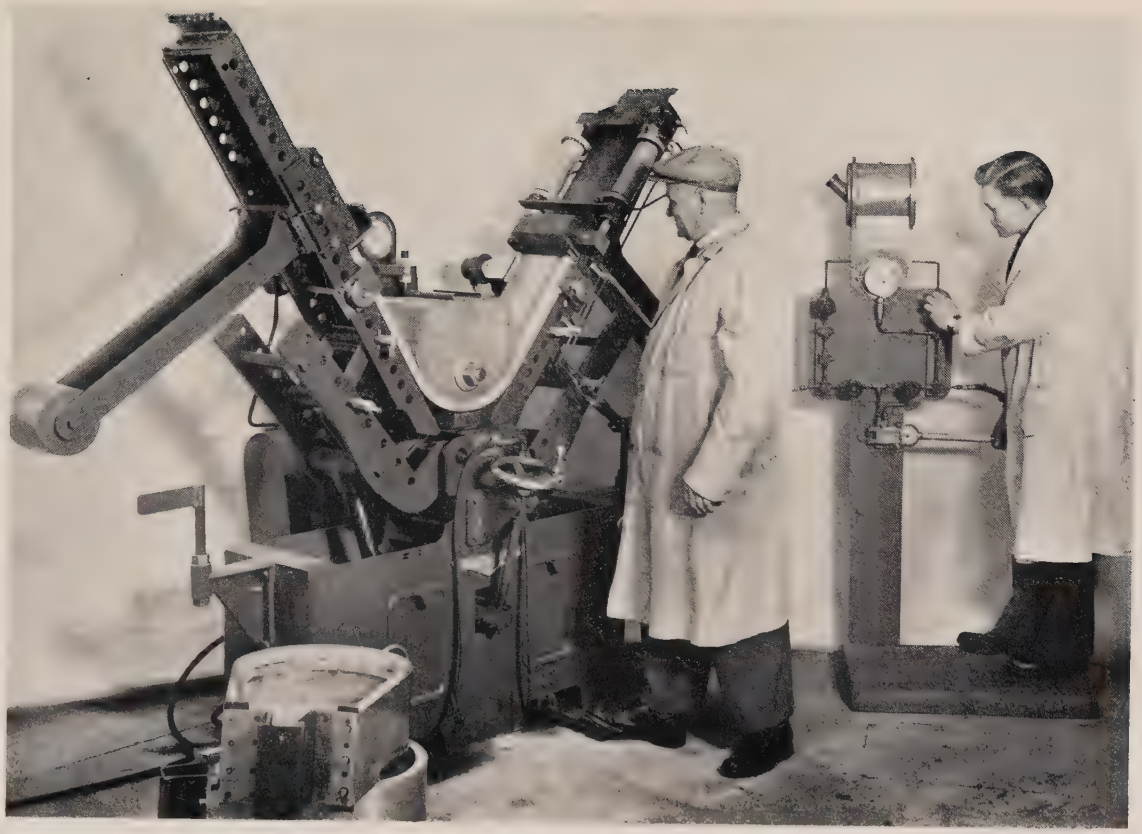
Part of the collection of specimen planks of timbers in the main building

PLATE 1



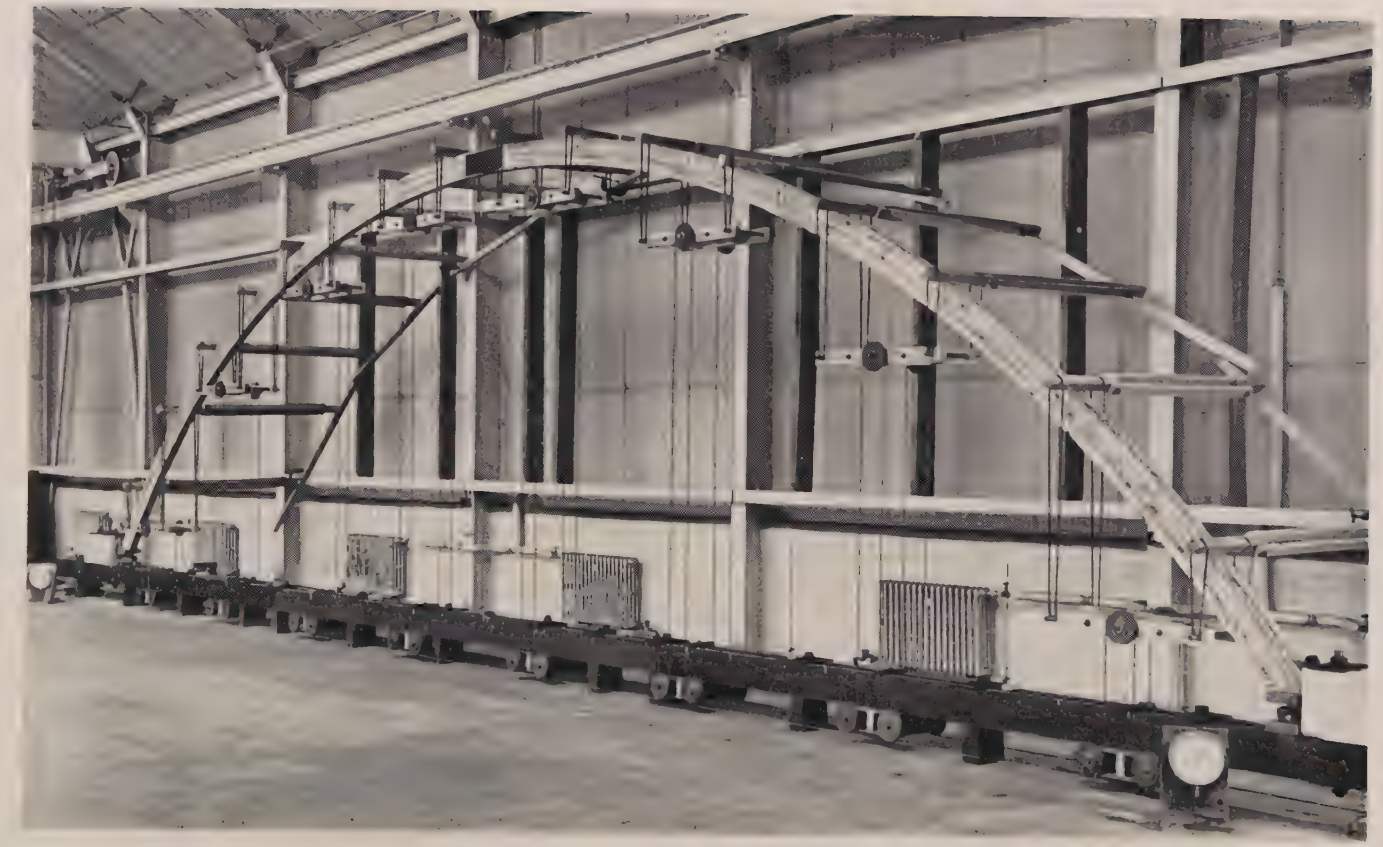
Board of African Mahogany showing rough surface and concentric zones of well developed tension wood (the darker zones) on the end grain

PLATE 2



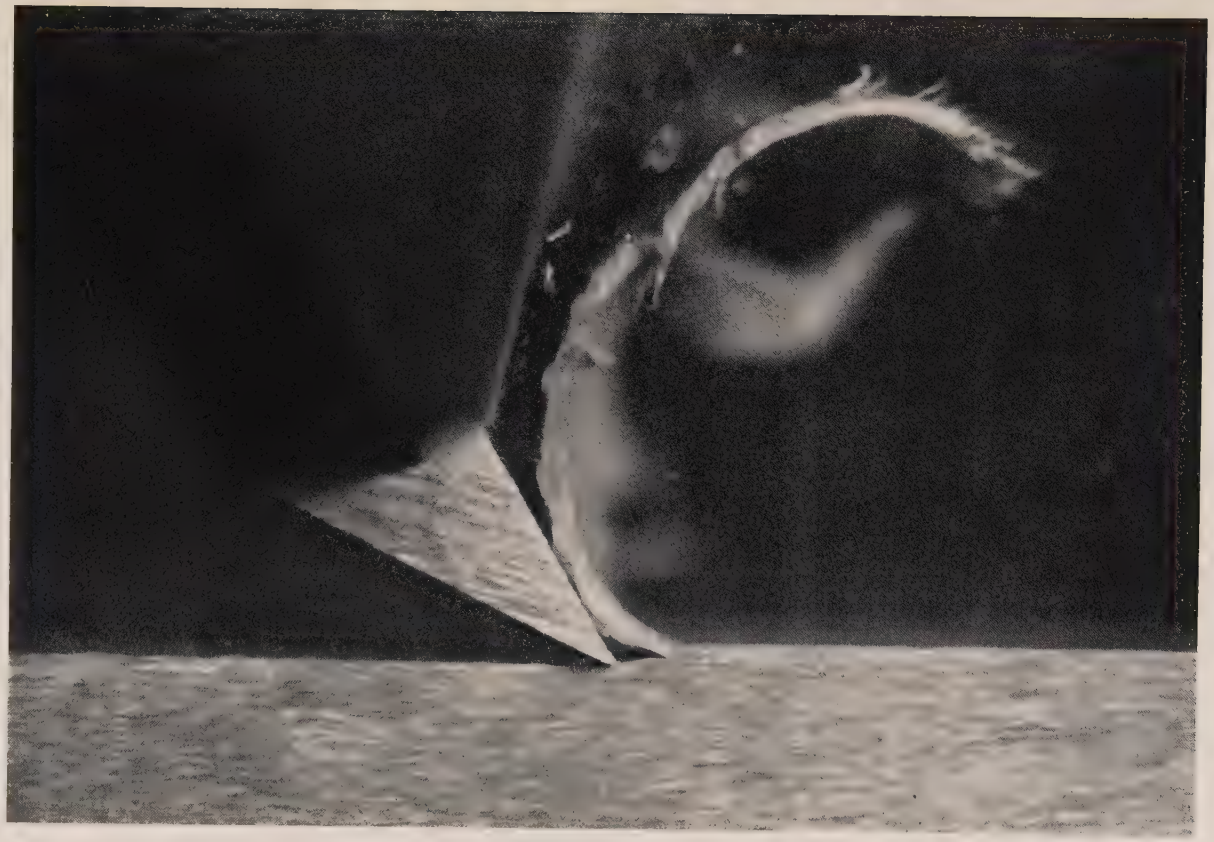
Hydraulically operated end stops for machine bending

PLATE 3



A laminated arch under test

PLATE 4



High-speed photograph of chip formation ($\times 9$)

PLATE 5

Sharpness angle 25°

Sharpness angle 35°

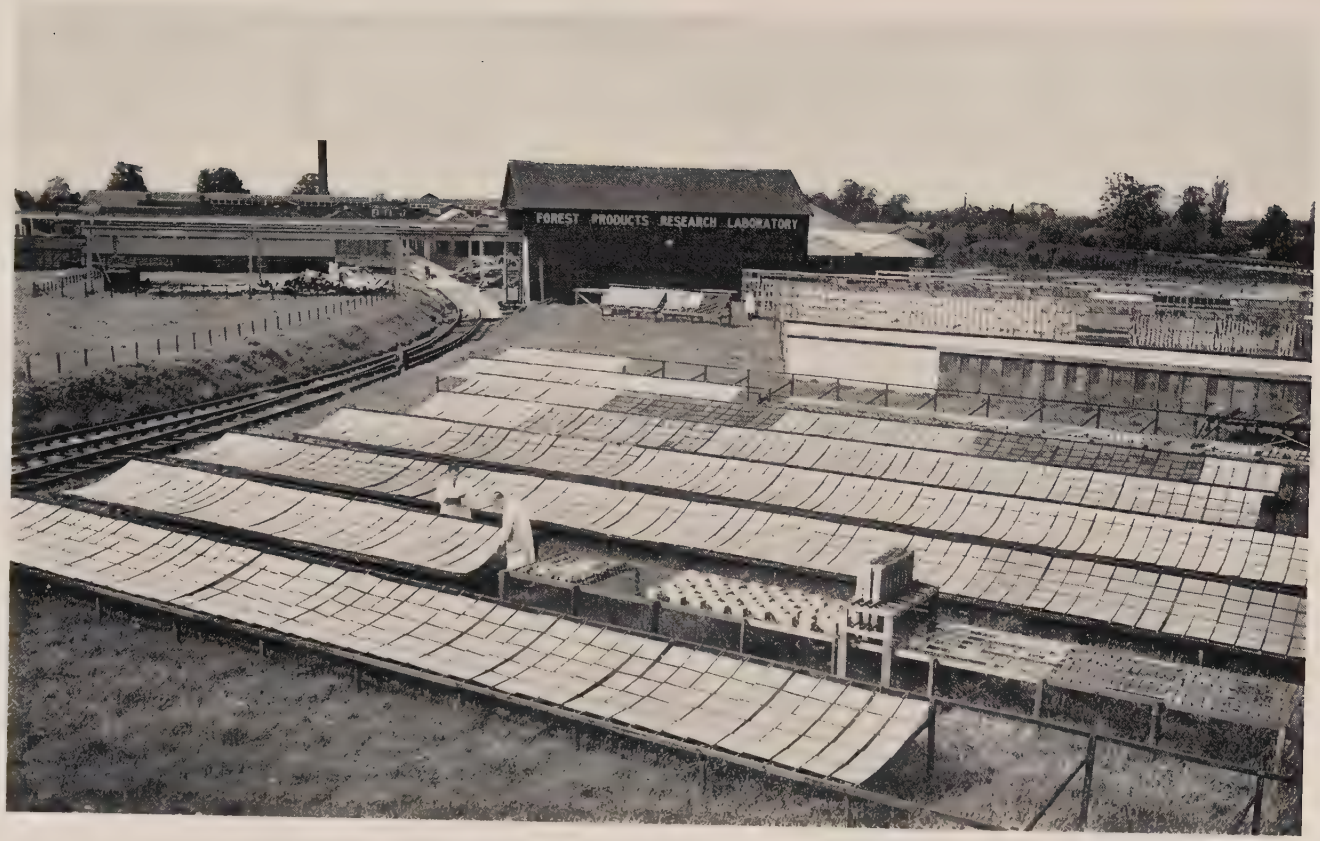
Sharpness angle 45°

Sharpness angle 55°

Silhouettes (×150) of edges after cutting 7,000 ft of beech at 30° cutting angle; original edge shown by pecked line.

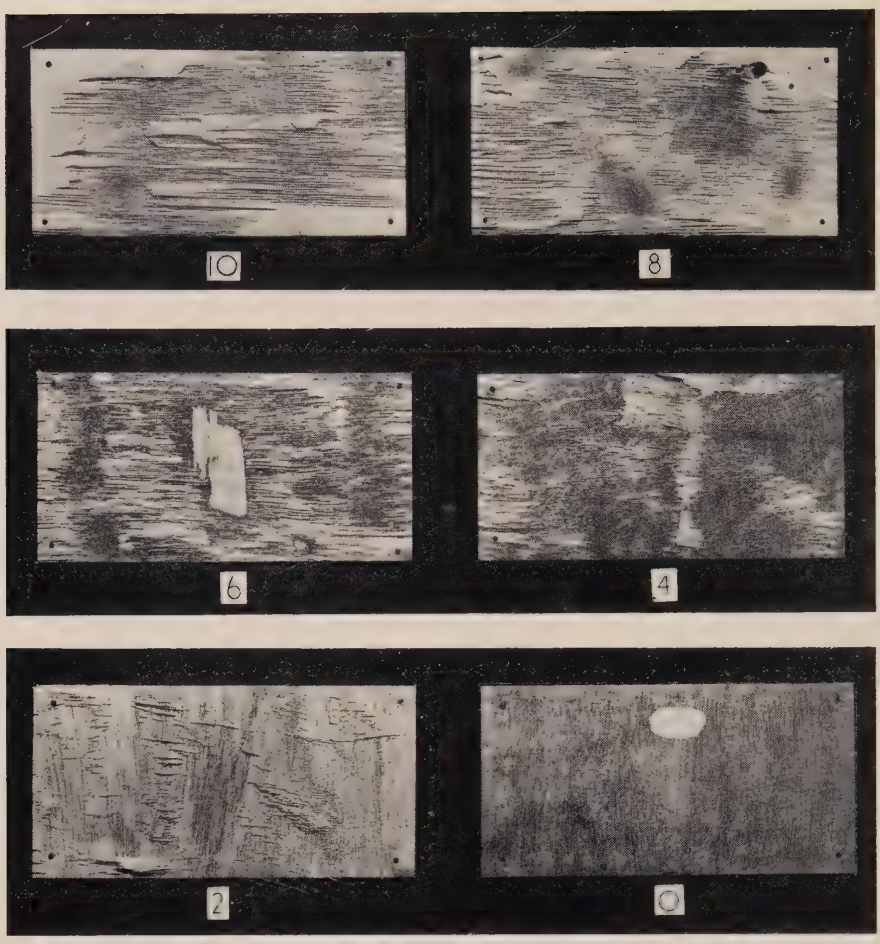
Effect of sharpness angle on blunting of H.S.S. cutting edges

PLATE 6



Weathering tests on plywood and other laminates

PLATE 7



Master set of knife-test specimens for the evaluation of bond quality in plywood

PLATE 8

when the same size of test block is employed identical toxic limits can be established by the two methods.

A further series of comparative tests on creosote, copper naphthenate and sodium fluoride has been undertaken to compare the soil/block contact method with the agar/block method and to compare the suitability of the local soil for such tests with that of soils from other parts of the country.

Permanence Tests. Leaching tests based on the method laid down in the German Standard DIN 2176 have been carried out on three water-soluble preservatives and comparisons made with non-leached series. Different methods for leaching have also been tried in order to improve the technique and to reduce the amount of time and labour required.

Blocks impregnated with sodium fluoride solutions and then leached and exposed to *Coniophora cerebella* suffered a significantly greater loss in weight than untreated control samples. Estimations of the amount of residual sodium fluoride at the end of the test revealed, however, that there was less than 0·3 mg in one of the blocks. Further tests are being carried out to confirm this stimulation of decay by impregnating wood with very dilute concentrations of sodium fluoride.

Laboratory Tests of Natural Durability of Timbers

Standard laboratory tests have been completed on the following timbers:— African mahogany, dahoma, muchenche, punah and home-grown cherry.

Tests were carried out on material from more than one tree and the samples were taken from the inner and outer zones of heartwood. In the African mahogany a striking difference in durability was found to exist between the inner and outer zones of the heartwood. Wood from the central zone around the pith was readily attacked, while the outer zone was definitely resistant, as the following figures show:

	Average loss in dry weight per cent after 4 months		
Test fungus	*Outer Zone*	*Intermediate Zone*	*Inner Zone*
Coniophora cerebella	5·1	4·9	33·7
Polystictus versicolor	2·2	15·7	34·3
Polystictus sanguineus	1·4	12·6	25·7

This means that great variability in durability may be expected between different samples of this timber—the outer heartwood may be classed as durable and the inner heartwood as non-durable. When it is particularly desirable to obtain material of high durability the logs of this timber should be converted so that material from the region of the pith is excluded. A further test on material from other trees is in progress to confirm whether such striking differences exist generally in this species.

The tests on further samples of cherry have not confirmed the suggestion that this timber may be highly durable, but have shown it to be very resistant to brown rots. The heartwood shows a much greater resistance to decay than the sapwood and, as with African mahogany, there is a tendency for the outer heartwood to be more resistant than the inner heartwood.

Tests of a compressed beech product suggested for use as inserts to hold the

spikes in concrete railway sleepers have shown that it is not resistant to fungal decay and would therefore be unsuitable.

Dry Rot Experiments

Further laboratory experiments on the efficacy against *Merulius lacrymans* of fungicidal solutions in contact with lime mortar and with bricks have indicated that sodium pentachlorophenate is effective when applied to cement/lime mortar at a concentration of 1 per cent and shows no diminution of effectiveness when re-tested some three months after application, but that its effectiveness is much reduced after leaching with water. Experiments with sodium o-phenyl phenolate indicate that the efficacy of this chemical is of the same order as that of sodium pentachlorophenate. Among other substances tested, a solution of the sodium salt of salicyl anilide at concentrations up to 5 per cent and borax at concentrations up to 8 per cent were found to be ineffective on cement/lime mortars against *Merulius lacrymans*.

As previously reported, wood impregnated with sea water shows increased resistance to attack by *Merulius lacrymans*. Further tests with sea-water impregnated samples retained at controlled relative humidities show, as might be expected, that they reach a much higher equilibrium moisture content (e.g. 24–25 per cent at 75 per cent relative humidity) than untreated samples. There may, therefore, be a risk that timber which has been impregnated with sea water will become affected with dry rot under the relatively dry conditions in which timber not contaminated with salt would remain too dry for infection to become established. It is difficult from laboratory tests to assess the relative importance of these factors in practice, but so far no reports of dry rot following flooding with *sea* water have reached the Laboratory.

Decay of Timber in Boats

Inspections of naval mine-sweepers and of Thames launches have been made during the year. Decay caused by micro-fungi (i.e. of the soft rot type) was found in the mahogany planking of the cabin tops and transomes of some launches of fairly recent construction. Some samples of African mahogany used in such boats appear to absorb water very readily even when covered with a good coat of varnish. The use of a water-repellent wood preservative for such planking was therefore suggested to the boat builder.

A further inspection was made of the *Cutty Sark* after the vessel had been brought into dry dock. The elm planking of the underwater portion of the hull was examined and found to be in good condition.

Sap-stain and Mould Investigations

Laboratory tests of sodium o-phenyl phenate and sodium pentachlorophenate as preventatives of sap stain by *Diplodia* species on ramin showed that concentrations of the chemicals required to give complete protection are much higher on this hardwood than on softwoods. Field-scale trials of sodium o-phenyl phenate and tri-ethyl tin for prevention of sap-stain on Scots pine boards have been carried out.

The mould resistance of covering materials for use in the tropics, such as linoleum and polyvinyl cloth has been investigated.

Prevention of Deterioration in Logs of Perishable Species

The second experiment on the protection of beech logs by means of antiseptic coatings was completed at the beginning of the year. Bolts which had been left lying on the grass in the shadow of a hedge for periods up to a year were sawn up and their condition examined. Decay caused by fungi such as *Stereum purpureum* and *Hypoxylon coccineum* was found to have extended throughout all the untreated bolts after twelve months' and very extensively after eight months' exposure. Nearly all the bolts that had been sprayed with a fungicide such as creosote or 5 per cent sodium pentachlorophenate and which had in addition a bituminous coating applied to the ends and branch stubs were practically free from decay. A paper describing these results has been published[26].

Advisory Work in Mycology

Enquiries dealt with by letter during the year totalled 1061.

ENTOMOLOGY

The Common Furniture Beetle, Anobium punctatum

General Life-history Studies.—Observations and experiments on the habits and rate of development of the common furniture beetle have been continued. In the course of work involving large-scale larval transfer, further data on the weight at which larvae pupate under out-of-door conditions have been obtained. Immediately after cessation of emergence in August, 1955, a hazel stick and portions of birch and alder plywood selected at random from an outdoor insectary were cut up for detailed examination and the uninjured larvae obtained were weighed; individuals weighing less than 1 mg. were discarded. The data obtained from the remaining 550 larvae, ranging in weight from 1·0–11·9 mg were arranged into arbitrary groups increasing by 1 mg and showed that in both materials a similar proportion of the insects was distributed throughout the weight range of 1·0–4·0 mg, there being a rapid fall in numbers of larvae of greater weight. It thus appears that in the material examined pupation had normally taken place when larvae had attained a weight of about 4·0 mg. This is supported by other data obtained at the end of May, 1951, when 33 pupating larvae from fencing had an average weight of 4·9 mg.

Experiments have been carried out to study the emergence of *Anobium* beetles. It is of practical interest to demonstrate whether beetles emerging, for example, from floor boards or panelling travel towards the light or the dark side of the infested wood. Observations on a section of severely infested plywood, part enclosed in a light-proof box and part uncovered, have indicated that there is a marked tendency for the insects to emerge on the light side. It has been noted that whilst males after emergence tend to migrate towards the light, females showed little choice between light and dark situations. Further work to amplify these observations is planned. Additional data from experiments have been obtained on the time of day at which egg-laying most frequently occurs with particular reference to conditions in a dwelling house.

Infestation of Plywood.—Work has been concentrated on the examination of birch plywood made up from veneers cut from logs either cold or after steaming, arranged into five arbitrary zones, 1 in. in width, and bonded with blood, blood/casein or urea-formaldehyde adhesives and subsequently exposed to infestation by the common furniture beetle (*vide* Report for 1953, p. 38). Counts have been

made of the numbers of eggs obtained on different experimental samples, and the results indicate that plywood made up from the second and third zones is preferred for egg-laying to that from the peripheral and inner zones; little choice appears to be shown between steamed and cold-peeled material. As in a series of similar experiments carried out in 1948 with beech and Scots pine, it now also appears that there is a marked preference for egg-laying on plywood made up with blood as compared with urea-formaldehyde glues; blood/casein glue, not included in the earlier work, appears to be less preferred than blood alone. These indications require confirmation, and a further experiment with improved technique is in progress.

For larval development it appears from the solid wood controls that steaming has rendered the wood more suitable: no marked difference was apparent between the zones whether from wood cut cold or after steaming. The rate of larval growth was greatest in the plywood made up with blood/casein glue; attack has made little progress in material with urea-formaldehyde or blood glues. This apparent unsuitability of blood glues is not in accordance with the results of past work and observations, and further experiments are in hand to reinvestigate the matter.

Investigations on Infestation of Decayed Timber.—Instances of more severe attack by *Anobium* in decayed as compared with sound portions of structural woodwork have again come to the notice of the Laboratory. For example, damage in a sample of maple flooring was largely confined to areas decayed by a white rot, probably *Daldinia concentrica*. In order to supplement data from earlier experiments on the relationship between fungal decay and *Anobium* attack a further series of oak sapwood and heartwood blocks has been decayed by the white rot fungus, *Phellinus cryptarum*, to a range of varying losses in weight and exposed to attack.

The House Longhorn Beetle, Hylotrupes bajulus

Occurrences.—No further instances of active infestation by this insect have been recorded outside those parts of North Surrey where it is known to be well established. A few cases of old attack, long extinct, have been recorded from buildings in other areas, notably in the London district, Westminster Abbey being a typical example. Observations have been made on infested houses in council property in Surrey to assess the value of insecticide treatments for eradication of existing attack.

Life-history Studies.—Emergence, oviposition, hatching and early larval development have again been studied and the results analysed for comparison with data obtained in previous years. It appears that in this country weather conditions throughout the summer, in particular temperature, are dominant factors governing the time at which the beetles emerge and also their numbers. In the comparatively cold summer of 1954 emergence did not start in laboratory stocks of infested material until August and only 27 adults were obtained. In the much warmer summer of 1955 emergence started in July and upwards of 50 beetles were found in the same material. The number of eggs laid have been correspondingly greater and for the first time during the study of this insect, which has extended over five emergence periods, eggs have hatched under normal out-of-door conditions.

Analysis of the biological information accumulated during this period and

comparison with published accounts of the life-history of the insect on the Continent and in the Union of South Africa suggest that the population of the insect in infested areas in the United Kingdom is less than normally found in countries where the insect is a more serious pest and that the life-cycle is longer. These factors combined with dependence upon favourable weather conditions for the hatching of the eggs probably explain the limited distribution of the house longhorn beetle in the United Kingdom and the cessation of attack in old buildings in which evidence of damage has from time to time been obtained.

Nutrition Experiments.—The initial experiments started in 1952 to compare the suitability of inner, middle and outer zones of the sapwood of Corsican pine for larval development of the house longhorn beetle have been completed. Samples taken from the different zones have been extracted with boiling water or acetone and newly hatched (egg) larvae inserted into treated and untreated blocks and their growth increment determined after approximately 12, 18 and 24 months. Despite large variations in the numbers and sizes of surviving insects, the results show the following trends: In untreated control blocks larval growth was faster and disintegration of the wood more extensive in the outer than in the middle and inner zones. In the water-extracted blocks larval growth was greatly inhibited, whilst in those treated with acetone, larval weights were similar to those in the untreated controls but less tunnelling had taken place. These results clearly suggest that water extraction removes at least some substances of nutritional value to the larvae of the house longhorn beetle; their confirmation and explanation are being sought by further work.

Other Longhorn Beetles

Callidium variabile (Phymatodes testaceus).—Examination has been completed of unbarked home-grown oak boards sawn through and through, treated with a 2 per cent emulsion of D.D.T. miscible oil in water, and exposed to attack by this insect in summer 1954. Complete protection has been obtained in all treated material, untreated controls showing satisfactory infestation.

These results indicate that this treatment, used for the protection of sawn oak and other hardboards against *Lyctus*, should also be effective against this longhorn beetle, which is commonly found along with *Lyctus* in the sapwood of sawn oak logs from which bark has not been removed.

The Death-watch Beetle, Xestobium rufovillosum

H.M.S. Victory.—In accordance with recommendations made to the Admiralty by the Pest Infestation and Forest Products Research Laboratories, following satisfactory results of the methyl bromide fumigation of H.M.S. *Victory* in April, 1954, before the emergence period (April–June), a second treatment was carried out on 19th May, 1955, by a commercial firm in co-operation with the Laboratories. The treatment was deferred until this later date—about half-way through the emergence period—in order to obtain further information on the effect of the 1954 fumigation. The following are the numbers of beetles collected on the ship during the past three years:

1953	5200	April–June: no fumigation
1954	938	April–June: fumigated before collection
1955	685	April–mid-May: before fumigation
	204	Mid-May–June: after fumigation

In comparison with the much larger numbers obtained in 1953 and preceding years, the figures for 1955 show that destruction of a substantial number of full-grown larvae present in the timber in 1954 and ready to emerge as beetles in 1955 was achieved by the first fumigation and indicate that the 1955 treatment has also been effective in killing beetles immediately before and after emergence.

Test samples were again placed in various positions in the ship before treatment but as this year's fumigation was carried out after most of the beetles had emerged and presumably laid eggs, small samples containing death-watch beetle eggs of known age were included, in addition to batches of adults. Analysis of the condition of this material after fumigation is not yet complete.

Westminster Hall.—Contact has been maintained with the Ancient Monuments Inspectorate, Ministry of Works, regarding infestation by the death-watch beetle in Westminster Hall and other public buildings. Data on the distribution of the beetles on the floor of the Hall during the emergence of the insect have been studied in relation to localized insecticide treatment and repairs which have been carried out annually. At the request of the architect in charge, the Laboratory was represented at a meeting at Lambeth Palace to consider treatment following evidence of the presence of the death-watch beetle in the roof of the Great Hall. Information collected by the Chief Architect's Division, Ministry of Works, in co-operation with the Laboratory, was placed at the disposal of the meeting, and arrangements were made for detailed observations in the Hall during the emergence period of the insect in 1955.

Ambrosia (Pinhole borer) Beetles

The Oak Pinhole Borer, Platypus cylindrus.—A study of the biology and food requirements of the oak pinhole borer, *Platypus cylindrus*, is being undertaken by the member of the West African Timber Borer Research Unit stationed at Princes Risborough. One of the chief objects of this work is to investigate fundamental problems of the relationships between insects and fungi which would be of value in connexion with the problem of infestation and prevention of attack by these insects in general. During the past year a study has been made of the population of *Platypus cylindrus* in two oak bolts stored at Princes Risborough, discs being cut off from time to time for detailed examination. Eggs, and young and mature larvae were found throughout the winter, indicating that egg-laying is continuous. There is some evidence of the existence of four larval stages. Fungal isolations have been made from tunnels and from the insects, but work on the nature of the "ambrosia fungus" is incomplete and is continuing. During the summer, field observations have been made on emergence and attack.

The results of a small-scale insecticide test carried out in 1954 in an East Anglian timber yard have shown that 1 per cent dieldrin and 0·5 and 0·25 per cent endrin, applied as oil/water emulsions at the rate of 1 gallon to 75–90 sq. ft of log surface gave complete protection from attack by this borer: 0·5 per cent dieldrin at a similar dosage was not completely effective. Expansion of this work was planned for 1955 but, owing to the lack of adequate test material in the timber yard, has been restricted to further experiments with dieldrin and with benzene hexachloride (gamma BHC).

Investigations in West Africa.—Close contact has been maintained with the work being carried out by the West African Timber Borer Research Unit on ambrosia beetles in the Gold Coast. The Officer in charge of the Unit spent some

days at the Laboratory whilst on leave early in the year, when the research programme was reviewed and the lines of future development laid down. His deputy on leave later in the year spent a week at Princes Risborough for work on insect collections and records of infestation.

Lyctus *Powder-post Beetles*

Prevention of Infestation in Sawn Logs.—Tests have been started to compare the value of a 10-second dip treatment of dieldrin (0·5 and 1 per cent) with D.D.T (1 and 2 per cent) and B.H.C (0·5 and 1 per cent) all applied as oil/water emulsions, for the protection of English oak boards from infestation by *Lyctus brunneus*.

Laboratory Tests of Wood Preservatives

Larval Transfer Technique.—Work has continued with the above method of evaluating wood preservatives, the timber used being confined to the outer inch zone of sapwood of Scots pine and Corsican pine.

Borax.—This cheap preservative has been shown to be effective for the prevention of attack by *Lyctus* powder-post beetles but few data are available on its toxicity to other wood-boring insects. With the object of investigating its value in this connexion experiments have been put in hand with the common furniture and the house longhorn beetles. A retention of 6·8 mg/cc was found to be effective at 22° C and 85 per cent relative humidity for destroying *Anobium* larvae when examined ten weeks after their introduction into treated samples.

Other Preservatives.—Similar tests are in progress with larvae of the house longhorn beetle in sapwood impregnated with aqueous solutions of preservatives of the acid-cupric-chrome and fluor-chrome-arsenate types.

Egg-laying Technique.—Larval transfer methods of evaluating the toxicity of preservatives against the common furniture beetle require the use of larvae of 1·0–2·5 mg. In order to compare the results obtained with such material with newly emerged *Anobium* larvae, blocks of Scots pine sapwood impregnated with borax, acid-cupric-chrome and fluor-chrome-arsenate preparations have been exposed for egg-laying to *Anobium* beetles using the muslin technique. After an adequate number of eggs had been laid, samples were stored at 22° C and 85 per cent relative humidity pending detailed examination.

Tests with Lyctus brunneus. *Pentachlorophenol.*—Investigations on the duration of the effect of pentachlorophenol applied to English oak sapwood by a 1-minute dip treatment for the prevention of attack by *Lyctus* are continuing. Samples treated with a 2·5 per cent solution became attacked after 12 months' storage under laboratory conditions. Samples treated with a 5·0 per cent solution were unaffected. Further material stored for two years has been exposed to infestation.

Orthodichlorobenzene.—A 10-second or a 1-minute dip treatment with subsequent ventilation for 35 hours at 30° C did not prevent attack by *Lyctus brunneus* in the sapwood of English oak. Treated samples were, however, less severely infested than untreated controls.

Other preparations.—Tests are in progress to compare the preservative value of aldrin and dieldrin in different formulations and concentrations

for the prevention of *Lyctus* attack in oak sapwood. Organo-tin compounds, lauryl pentachlorophenol and benzene hexachloride preparations are also included in this work.

Siricid Wood Wasps and Australian Quarantine

Numerous requests were received by the Laboratory, from a wide range of industries exporting goods to Australia in softwood packing cases, for advice on how to meet the recently intensified quarantine regulations to prevent the introduction of Siricid wood wasps into that country. Careful consideration of possible methods of treatment of timber and packing cases to ensure the destruction of any wood wasps present has led to the conclusion that fumigation with methyl bromide, if proved effective and economically practical, offered the most likely solution to the problem. With the co-operation of the Pest Infestation Laboratory, the Timber Development Association, and a commercial fumigation firm, a series of field tests was carried out involving the treatment under gas-proof sheets of stacks of packing case timbers, $\frac{7}{8}$ in. by 4 in., of redwood and whitewood. These tests were supplemented by laboratory studies (see below) of the toxicity of methyl bromide to *Sirex* larvae removed from the wood and of the powers of penetration of the fumigant into timber of different thicknesses.

The results of this work have shown that *Sirex* larvae are highly resistant to methyl bromide and that for some types of 1-in. boards twice the dosage required to kill insects removed from the wood may be necessary for insects within, and have led to the conclusion that fumigation for the complete destruction of *Sirex* would require such high doses of methyl bromide as to be impracticable. Accordingly, this method of treatment is not recommended as a means of satisfying quarantine requirements by ensuring the destruction of all insects which might be present at the time of fumigation.

A general account[27] of this investigation with comments on alternative treatments and a wall chart suitable for display in timber storage premises and factories to facilitate recognition of the type of damage caused by *Sirex* have been published.

Toxicity of Methyl Bromide to Wood-boring Insects

Arising out of *ad hoc* investigations involving fumigation of timbers of H.M.S. *Victory* and field tests with packing-case timbers for the destruction of *Sirex* wood wasps, a start has now been made on laboratory experiments in co-operation with the Pest Infestation Laboratory to obtain basic data on the powers of resistance of various stages of wood-boring insects to methyl bromide. The results of work so far carried out are summarized as follows:

Sirex *Wood-wasps*, S. juvencus.—Larvae of various sizes, including pre-pupal stages, removed from logs of home-grown Norway spruce were submitted to a range of dosages of methyl bromide, recorded as concentration/time products of 100–810 mg h/l. It was found necessary to keep larvae under observation for several weeks after treatment before their condition, as compared with that of untreated controls, could be reliably established. This work has shown that *Sirex* larvae are exceptionally resistant to methyl bromide, 100 per cent kill being obtained three weeks after treatment only at a concentration/time of 810 mg h/l. At lower dosages, e.g. at concentration/times of 335 and 510 mg h/l, some larvae recovered after treatment and in some instances pupated.

The Death-watch Beetle.—Eggs of known age were treated at concentration/times of 50–200 mg h/1. A small number hatched at the lowest dosage, but evidence of post-treatment development of eggs without successful hatching was observed at dosages up to a concentration/time of 100 mg h/1.

Adults of varying age collected from buildings were treated at approximately the same range of dosages as the eggs. A kill of 100 per cent was obtained six days after treatment at all dosages except the lowest (c./t. 50), at which some beetles were alive thirteen days after treatment. Whilst these results give some indication of the toxicity of this fumigant to the death-watch beetle, supplementing the observations on H.M.S. *Victory*, additional information is necessary and further experiments are planned for 1956.

Destruction of Wood-boring Insects by Gamma Ray Treatments

Following the recommendation of a representative committee which considered the sterilization of the timbers of H.M.S. *Victory* by radiation treatments, preliminary experiments on a laboratory scale have now been begun in co-operation with the Radio Isotope Division of the Atomic Energy Research Establishment, Harwell.

The objects of this work are to ascertain the required dosages for (1) killing eggs, larvae and beetles, (2) affecting the development of larvae or causing them to produce sterile beetles, and (3) sterilizing beetles. For this work a Cobalt-60 source of gamma rays was used. The following is a summary of the experiments so far carried out.

Powder-post Beetles (Lyctus brunneus).—Larvae irradiated at dosages varying between 8000 r and 150 000 r survived for periods roughly in inverse proportion to the dosage received but all died much sooner than did the controls; it appears, however, that very high dosages would be needed to secure rapid death. Larvae completed their development and emerged as beetles from oak sapwood irradiated at dosages from 16 000 r to 72 000 r but none laid fertile eggs. Infertile eggs were laid by females irradiated at 16 000 r and 32 000 r. A further experiment has been set up to investigate the effect of lower dosages.

The Death-watch Beetle.—Eggs of this insect were irradiated at dosages of from 1000 r to 16 000 r. Hatching was prevented at dosages of 4000 r upwards, the minimum lethal dose lying between 2000 and 4000 r.

The Common Furniture Beetle.—Eggs of varying age and free beetles have been treated at dosages ranging between 125 and 16 000 r, but the results of this work are not yet available.

Sterilization of Insect-infested Timber by High Frequency Treatments

Experiments on the destruction of wood-boring insects by high frequency currents have been carried out in co-operation with the British Electrical and Allied Industries Research Association using samples of *Lyctus*-infested oak sapwood and electric fields of varying frequencies for different periods of time. The material was treated in piles of varying heights to simulate boards of different thicknesses. Larval mortality of 100 per cent was obtained in most instances when the temperature of the wood rose to above 60° C, larval temperatures exceeding this figure because of their higher dielectric constant. The exposure period required for such temperatures to be reached within the wood

varied from 15 seconds for 1½ in. thicknesses to 60 seconds for 2 in. thick material, using an apparatus with a high frequency output of 250 watts operating at 75 Mc/s.

Further experiments have been planned in co-operation with the Research Association, using exposures of 5-15 seconds and fields of higher power. The large quantity of *Lyctus*-infested sapwood required for this work is now being prepared from laboratory cultures of the insect.

Advisory and Inspection Work in Entomology

There has been a marked decrease in the number of enquiries dealt with by correspondence during the year; these amounted to 944. Fourteen inspections of outside property have been made but as in recent years it has not been possible to meet all the requests for such work.

CHEMISTRY

Wood Polysaccharides

Hemicelluloses from Beech.—The studies on the hemicelluloses from beech[28] are being continued. Hemicellulose B, prepared by extraction of the delignified wood with 4 per cent sodium hydroxide, was converted into its methylated derivative, but it was evident that considerable degradation had occurred during this process. It has been shown elsewhere[29] that even the fractions of beech hemicellulose which are difficult to dissolve can be obtained in a relatively undegraded condition by direct extraction of the wood with sodium hydroxide, without preliminary delignification. This method was used, therefore, for the preparation of larger quantities of material. Hemicellulose A was removed as described previously[28] by exhaustive extraction of beech sawdust with 4 per cent sodium hydroxide, and a further fraction (2·8 per cent) was then isolated from the residue by extraction with 17·5 per cent sodium hydroxide under nitrogen, the hemicellulose being precipitated from the acidified solution by the addition of ethanol.

After purification and examination the hemicellulose prepared in this manner will be compared with hemicellulose A and with hemicelluloses B and C isolated from holocellulose prepared by the chlorite technique.

Oligosaccharides in Wood

A Scots pine branch (cut 21.6.55) was debarked and converted into sawdust, which was immediately immersed in boiling alcohol. Water was added to bring the final alcohol concentration to about 70 per cent and the mixture was heated under reflux. An examination of the extract by means of paper chromatography indicated the presence of glucose, fructose, sucrose, raffinose and another constituent of R_G value similar to that of stachyose. Examination of ash wood by the same method gave results similar to those above. In neither case was there any evidence of the presence of a range of oligosaccharides such as that encountered in a previous investigation of Scots pine[30]. This discrepancy cannot be explained at present.

Morabukea Saponins

A study of the saponins isolated from the heartwood of morabukea has shown that they provide an interesting example of variation in a natural product. The

general nature of the saponins had already been established[31],[32] but it has now been shown that the products isolated from different logs of morabukea may vary considerably in composition. A second example extracted from a further log of morabukea has been studied in detail. While its constitution was found to be similar to that of the material examined previously, considerable differences in structural detail were apparent. Both products are mixtures of several closely-related constituents and it is evident that the proportions in which these are present may vary widely. Thus, while the product first investigated was found to contain about 6 per cent by weight of galactose residues, the second preparation gave only very small amounts of galactose on hydrolysis. Further, the second preparation was shown to contain a relatively large proportion of 1 : 2-linked glucose residues, which are somewhat uncommon in nature. Further insight into the arrangement of the constituent sugar residues in this material was obtained by examining the product prepared by Barry degradation of the sample. A paper embodying the above results has been published[33].

Wood Extractives

Indian Rosewood.—As already reported this wood contains a high proportion of components which can be extracted by means of solvents. The alcohol-soluble material (31·7 per cent of the dry weight of wood) gave, on fractionation, a series of products, all of which were highly coloured, but which appeared to be of rather indefinite composition.

Extraction of the wood with petroleum ether (boiling point 60–80° C) yielded an extract which contained a colourless crystalline substance and a brown tar. The crystals were separated and purified by washing with carbon tetrachloride and recrystallizing from aqueous alcohol; their melting point was 123° C, and yield 0·5 per cent of the weight of the wood. The substance had phenolic properties and analysis indicated the presence of two methoxyl and two hydroxyl groups. The latter could be acetylated with acetic anhydride in pyridine, yielding a di-acetate, melting point 125° C.

East African Mulberry (Morus lactea).—This timber contains a bright yellow colouring matter which has been somewhat troublesome in experimental work on the steam-bending of wood. The yellow dyestuff contaminates the steaming chamber and discolours any other wood with which it comes in contact. Several species of *Morus* contain colouring matters. For example, it is known that the wood of *Morus tinctoria* contains the colouring matters morin (a pentahydroxyflavone) and maclurin (a pentahydroxybenzophenone).

The aqueous extract of *Morus lactea*, prepared by extraction of the sawdust in a Soxhlet apparatus, was treated with lead acetate and the resulting precipitate decomposed with sulphuric acid. The acid solution was decanted from the lead sulphate and the product isolated by extraction with ether and crystallization from aqueous ethanol. Chromatography of this material on a cellulose column using 15 per cent acetic acid as eluting agent indicated the presence of two crystalline substances, one of which was shown to be morin by its reactions, chromatographic behaviour, melting point, and mixed melting point with an authentic specimen.

The properties of the second, faster-moving compound indicated that it also possessed a flavonoid structure. It crystallized from water as a hydrate which lost water of crystallization at 135° C and melted at 224° C. When chromato-

graphed on paper it had R_F values of 0·87 in butanol-acetic acid-water (4:1:5) and 0·53 in 15 per cent acetic acid, and could be located as a brown spot under ultra-violet light or as a bright orange-brown spot when sprayed with diazotised p-nitroaniline in sodium acetate. Although the substance was colourless it dissolved in sodium carbonate to give a yellow solution, and was also soluble in sodium bicarbonate solution. On reduction with magnesium and hydrochloric acid it turned to a bright pink colour, a reaction characteristic of flavanones and flavanols, and its solution in ethanol gave a brown-violet colour with ferric chloride.

Phenolic Components of Inner Bark.—The soft, light-coloured inner bark of trees represents a region of possible physiological interest in view of its close proximity to the cambial region. From a chemical point of view it remains largely unexplored, although it is known that polyphenols of the anthocyanin class are frequently present. Some preliminary observations have therefore been made on the inner bark of over twenty tree species in order to obtain information on the general types of phenolic substances present. The examination of the materials included (1) tests for leuco-anthocyanins by boiling with alcoholic hydrochloric acid, (2) tests for substances of the chlorogenic acid type by the Hoepfner test (acetic acid and sodium nitrite, followed by alkali), and (3) chromatography of extracts on paper before and after hydrolysis. No generalizations can be made from this very limited survey, but it is noteworthy that both leuco-anthocyanins and substances responding to the test for chlorogenic acid were found to be present in appreciable amounts in the great majority (but not all) of the inner barks examined, and were also frequently found in smaller amounts in the corresponding wood samples. Many of the inner barks rapidly turn brown on exposure to air in a manner resembling the browning of freshly-cut apples; in the latter case this is thought to be the result of oxidation of chlorogenic acid. It is possible, therefore, that the further study of these poly-hydroxy-phenolic substances may throw some light on the colour changes which occur during drying and ageing of wood.

Production of Hardboard from Secondary Colonial Timbers

In the course of experiments with several dense Colonial hardwoods, boards having good strength properties were readily made by means of the modified neutral sulphite semi-chemical process studied, and two papers have been published describing the results of the trials with four Malayan timbers[34]. In the case of certain timbers, however, some difficulty was experienced in producing boards having the required degree of water resistance. Various methods whereby the water absorption of the boards may be reduced have now been investigated in order to compare their effectiveness and their influence on strength and stability of the boards. Pulp prepared from morabukea was used for this series of tests since previous work on this species had shown the need for special treatment in order to reach B.S. requirements for water resistance (maximum absorption in the standard test: 30 per cent for standard hardboard and 20 per cent for super hardboard).

The following methods of treating the boards during manufacture were compared:

(1) Heat treatment in circulating air at 180° C for various periods of time after pressing.

(2) Adjustment of the pulp suspension to a slightly acidic condition before pressing, followed by heat treatment as in (1).

(3) Application of a drying oil immediately after pressing, followed by heat treatment as in (1).

(4) Addition of wax emulsion to the pulp suspension.

(5) Addition of synthetic resin to the pulp suspension.

All the boards were made from wet mats containing about 80 per cent water, and a standard pressing procedure with a maximum pressure of 1000 Lb./sq. in. and a temperature of 180° C was adopted. Control boards were also made from untreated pulp without any after-treatment and had an average modulus of rupture of 6750 Lb/sq. in., specific gravity 1·09 and water absorption 74 per cent. The pH of these boards and of the pulp suspension from which they were made was 6·45.

Hot-air treatment of the boards at 180° C for periods up to 4 hours progressively reduced their water absorption from 70 per cent to 33 per cent. The strength of the boards increased slightly during the first 2 hours' heating, after which there was a small decrease on further heating to approximately the original value after 4 hours.

Boards pressed from pulp adjusted to pH 5·5 by addition of sulphuric acid and alum had the same average bending strength as those from untreated pulp, but their water absorption was 60 per cent. This was reduced to 33 per cent by heating for 2 hours at 180° C, but there was a distinct reduction in strength even after 1 hour.

Further acidification of the pulp to pH 4·5 resulted in boards having the same average initial strength, but the water absorption was now 48 per cent. Although this was reduced to 25 per cent by heating for 2 hours at 180° C, the weakening effect of the heat treatment was more rapid in this case, the modulus of rupture being reduced to 4900 Lb/sq. in. (the minimum value for standard hardboard) after 2 hours' heating. Some further loss in strength might be expected during ageing of boards treated in this way.

Treatment of boards while hot from the press with a fine spray of linseed oil proved to be a satisfactory method of reducing their water absorption to the level required by the specification. Addition of 3 per cent of oil, followed by heat treatment for 2 hours at 180° C, reduced the absorption to less than 30 per cent and at the same time resulted in a considerable gain in strength (modulus of rupture over 9000 Lb/sq. in.).

Addition of wax emulsion to the pulp suspension was also very effective in reducing the water absorption of the finished boards. Incorporation of 1 per cent or 2 per cent of wax in this way reduced the absorption to 22 per cent or 15 per cent respectively. However, the addition of wax also caused a progressive loss in strength, and boards containing 1 per cent or more barely met the minimum strength requirements for standard hardboard.

Finally, the addition of a specially prepared phenolic resin to the pulp resulted in a considerable gain in strength in the boards, but only a relatively small improvement in their water resistance. The resin syrup was added to the pulp suspension, which was then acidified to pH 3·0–3·5 with sulphuric acid and alum to precipitate the resin on the fibres. After sheet-forming, pressing and

conditioning, the finished boards had pH 4·5, a water absorption of 36 per cent and a modulus of rupture of over 9000 Lb/sq. in. As reported above, adjustment of the pH to this level alone had the effect of reducing the water absorption to 48 per cent, so the further improvement brought about by the P/F resin was not very great, though the gain in strength was substantial.

It was found possible to combine the effects of wax and resin so that the losses in strength due to the addition of wax alone were offset by gains due to the presence of the resin. Thus, boards containing 1 per cent of wax and 0·5 per cent of resin had water absorption values as low as 13–13·5 per cent together with a modulus of rupture of 8000–8500 Lb/sq. in.

Corrosion of Metals in Association with Wood

Work has been carried out intermittently since 1942 on the subject of the corrosion of metals in the presence of wood. Although this has not formed one of the major research projects of the Laboratory a good deal of attention has been devoted to it, and a steady stream of enquiries is received on various problems involving corrosion of metals. Thus, in 1955, 31 enquiries were dealt with bearing directly or indirectly on this subject. The related subject of the electrochemical action taking place between dissimilar metals in contact with wood, and the resultant breakdown of the wood, has recently been discussed[35]. Further consideration has now been given to certain aspects of the corrosion of metals in association with wood.

Corrosion of Aluminium.—The factors governing the corrosion of aluminium in wood/aluminium assemblies were discussed briefly in 1950[36] and it was indicated at that time that further investigations were desirable. A series of trials has now been begun, in co-operation with the Aluminium Development Association, in order to gain further information on the extent of corrosion occurring in aluminium and aluminium alloys in contact with a number of woods, with and without preservative treatment. The following materials are included in the trials:

Metals: commercial purity aluminium sheet, SIC; duralumin-type alloy, HS14-T; diecast plates, LM4-M.

Woods: oak, European spruce, beech, obeche, Douglas fir, African mahogany, balsa, greenheart, elm, western red cedar.

Preservatives: creosote, water-soluble and oil-soluble preservatives.

The corrosion trials are being carried out on composite specimens consisting of a sample of the metal screwed to a block of the appropriate wood. These specimens are set out on exposure racks out of doors at two sites, viz. (1) a rural atmosphere and (2) a marine atmosphere, and sufficient specimens of each wood/metal combination are being exposed to permit of removal of specimens for examination at four time intervals.

The three metals are each exposed in contact with oak, spruce and obeche, while the seven remaining timbers are attached only to commercial purity aluminium. This metal is also used in the trials involving wood treated with each of the four preservatives. Examination of the metal specimens after exposure will be undertaken by the Aluminium Development Association and will include micro-examination for depth of attack, loss in weight and tensile testing.

Corrosion by Volatile Components of Wood.—Enquiries have been received

from manufacturers of radio sets regarding the cause of serious corrosion of cadmium-plated parts, which occurs when the sets are exported to tropical countries and kept in their packages for a time before distribution. The radio cabinets are made of birch plywood with smaller amounts of various other woods used as framing. No corrosion has been reported in sets having plastic cabinets, and the makers of the sets provided evidence that the corrosion was associated with certain woods present in the cabinets.

In order to ascertain the cause of the corrosion small specimens of cadmium-plated steel were suspended in closed vessels under warm, moist conditions, over samples of a number of woods, and also over certain chemicals which might possibly be derived from wood or from the glues used in the assembly of the cabinets. It was found that the most actively corrosive material tested was acetic acid, which produced heavy rusting of the steel under the cadmium plate in a few hours. Formic acid also caused severe rusting, but rather less rapidly. Of the ten wood species tested, oak and birch were the only ones to cause severe corrosion in the duration of the experiment (two months), although some other woods produced either a grey deposit or incipient rusting at the end of this period. The corrosive properties of oak are well known and are probably due to the acetic acid evolved by this wood, but the results obtained with birch were unexpected and are relevant in view of the use of birch plywood in the radio cabinets. Birch has not hitherto been regarded as an acidic or corrosive timber, the reference pH value of the moist wood being 4·5 (compare oak, pH 3·3–4·4; Douglas fir, pH 3·1–3·7). It must be concluded that, although birch is not unusually acidic under ordinary conditions a progressive development of acidity takes place when the wood is kept at an elevated temperature and high humidity. This development of acidity is much greater than it is with certain other timbers of similar initial pH value, e.g. African mahogany or Parana pine, so the pH of the moist wood is not a reliable guide to the extent of corrosion which it might cause under these conditions. Further experiments are in progress to follow quantitatively the development of acidity and to determine if possible the nature and origin of the acid produced.

Occurrence of Salt in Wood.—A problem which, although not of common occurrence, is nevertheless of some interest concerns the corrosion of metals in contact with wood in circumstances where such corrosion would not normally be expected. Examples which have been seen in recent years include corrosion of metal parts in a piano action, of a saw blade where it is held in the handle, of nickel-plated sheaths covering wooden coffin handles, of steel cables on a wooden drum and of metal tags on a wooden rail in a telephone exchange. In all these instances the wood was reasonably dry and there was no immediately apparent reason why corrosion of metals should have taken place to the extent observed, but in each case closer investigation showed that the wood contained an appreciable proportion of a salt, usually sodium chloride. Thus in the piano action all screws and fittings attached to a maple beam rail and a few other maple parts were severely corroded while metals in contact with components made of other woods were free from corrosion. It was found that the maple rail had a salt content varying from 1·4 per cent at one end to 4·0 per cent at the other. It is well known that sodium chloride is corrosive to most metals and there is little doubt that it is the direct cause of the corrosion in all these cases. It is difficult to ascertain the origin of the salt because it is not usually possible to trace the history of the particular piece of wood concerned, but the most reasonable hypo-

thesis would seem to be that the salt enters the wood during floating of the log in salt water. If a log is partly submerged in salt water and evaporation takes place from the exposed surface, then it would be expected that salt would accumulate in the upper part of the log and might build up to quite high concentrations.

Advisory Work in Chemistry

As in previous years the subject matter of the enquiries covered a wide field. In a considerable number of instances, for example those referring to the irritant properties of certain timbers, discolorations in timber, exudation of resin, odours arising from wood, and certain types of deposits in wood, the difficulties are directly related to the minor constituents of the woods concerned, and emphasize the lack of detailed information on the constitutents present in many woods and the need for further study of them. Many enquiries also continue to be received on the selection and treatment of timber for use in situations where it is liable to chemical attack, for example in vats and filter presses, derusting and pickling tanks, plating baths, bleaching chambers, lime pits, etc. Examination of timber stacked in a yard in an industrial town in Lancashire showed that the exposed surfaces of the timber were in an undesirably acidic condition, having presumably absorbed acidic fumes from the atmosphere. This raises the question of the advisability of storing timber unprotected in industrial atmospheres for long periods.

The number of external enquiries dealt with by letter during the year was 194 and advice was given to 44 technical visitors.

PHYSICS

Moisture Movement and Distribution in Wood

Experiments have continued on the moisture movement and distribution in 1 in. thick Douglas fir discs. One face of the discs was in contact with water and the other exposed to an atmosphere kept dry with phosphorus pentoxide. The thickness direction of the discs lay in the tangential direction of the wood which was therefore the direction of flow of moisture. One set of experiments was carried out starting with the disc waterlogged, and a second set starting with the disc air dry. The initially air-dry discs took about three weeks to come to a steady state as indicated by the time required for the rate of moisture movement through the discs to become constant. The initially waterlogged discs were much slower and did not become steady until about three months from the start of the experiment.

After reaching the steady state, the discs were cut up for the determination of moisture distribution. In this instance also there was a considerable difference between the two sets of specimens, shown in Fig. 2, which gives the moisture distributions as determined on the individual discs. It will be seen that although the fall in moisture content with distance is very sharp whatever the initial state of the specimens, at the same time the moisture content at a given distance from the wet face is always higher in the initially waterlogged specimens. These experiments are now being repeated on beech.

Measurements were made some years ago of the rate at which moisture was taken up when pine specimens conditioned at one relative humidity were exposed

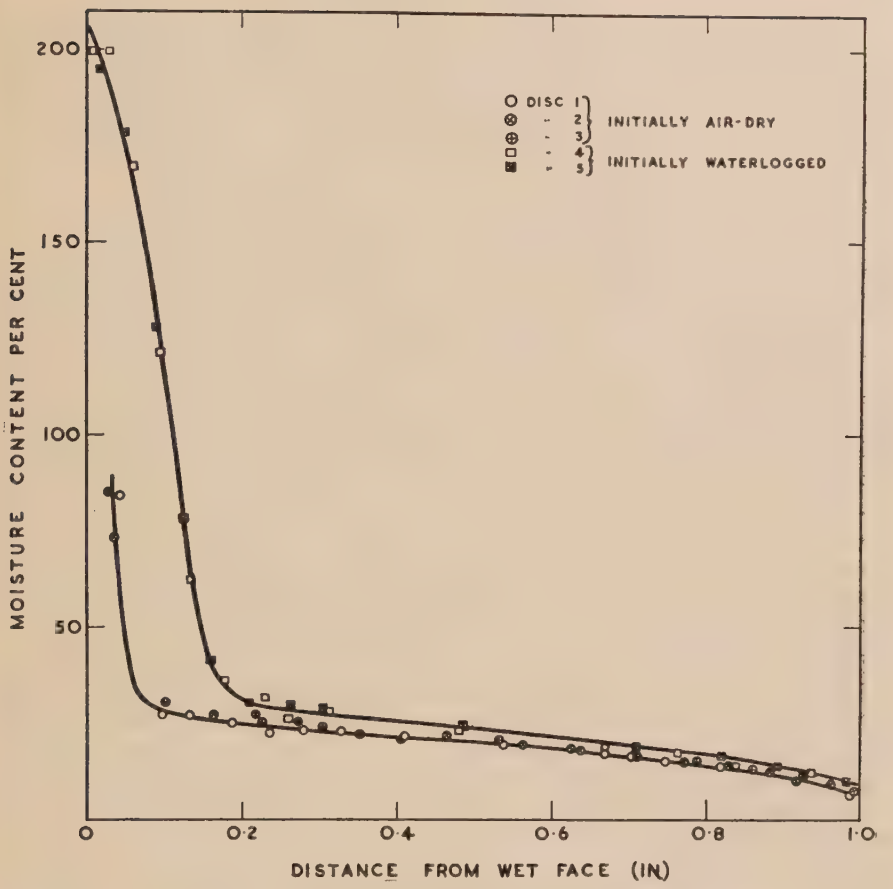


FIG. 2. Moisture distribution in Douglas fir discs

at another relative humidity. From the results of these experiments, it is possible to derive the diffusion coefficient of water vapour in wood, and the experiments are now being extended to oak and beech with the object of finding the variation in diffusion coefficient from one species to another.

Elastic and Allied Properties of Wood

Work has continued on the behaviour of wood and plywood in vibration, a subject which has attracted the attention of a number of workers in other laboratories. During the past year, relatively simple formulae have been derived for the frequency of all modes of transverse vibration of rectangular wood and plywood plates, subjected to any combination of supported and clamped edge conditions. The frequencies of square plates as given by these formulae have been compared with those obtained elsewhere by a much more elaborate method and good agreement obtained between the two sets of figures.

The design of the apparatus used in this Laboratory for exciting wooden beams into bending vibration has been improved, and it is now possible to work at higher frequencies and with higher modes of vibration than formerly.

Quantitive study of the bending vibrations of wood is often applied to the measurement of the modulus of elasticity and of the damping of vibration. The modulus of elasticity is usually calculated assuming simple bending theory to apply, but closer examination shows that this assumption is only valid if the beam is very long compared with its lateral dimensions. Under other conditions there is some shear in the beam, and one of the objects of the present work is to assess quantitatively the effects of departure from the simple theory.

The experiments carried out at this Laboratory have involved modes of vibration up to the 10th mode, but elsewhere, measurements are available up to the 16th. These results have been examined and it has been found that the interpretation which fits the Laboratory's results up to the 10th mode is also valid for the other results up to the 16th mode. In the case of a specimen measuring 182 by 3·7 by 2 cm vibrating in the 16th mode with the plane of bending parallel to the larger cross-sectional dimension, the observed frequency is only 2/3 of that calculated from standard bending theory, ignoring shear effects. In practice, it is unlikely that a mode of vibration as high as the 16th would be used in the determination of modulus of elasticity but the Laboratory's results show that on a beech specimen measuring 83 by 5 by 2·5 cm, the observed fundamental frequency is 3 per cent lower than that calculated from simple bending theory. Since the modulus of elasticity depends on the square of the frequency, this would mean a 6 per cent error in the modulus, and it is evidently necessary under these circumstances to allow for the effects of the shear in interpreting the results.

Opportunity has also been taken of measuring the damping in the lower modes of vibration. Early workers on the damping of vibrations in wood claimed that this property was independent of frequency. More recently, it has been stated that it is proportional to frequency and it was hoped that by making measurements on the same specimen vibrating in different modes, the effect of frequency could be established unambiguously. Unfortunately, this has not proved to be the case because the results are rather scattered. There does seem to be some increase in the damping at the higher frequencies, but this may be due to the fact that in general the higher the frequency, the greater is the amount of shear involved, so that the measured damping is not that appropriate to pure bending.

To discover whether they would be of use in the diagnosis of decay, vibration tests have been carried out on fifteen beech specimens, nine of which were in the early stages of attack by a white rot fungus, while the other six were unattacked and served as controls. The moduli of elasticity and the damping were calculated from the results; the moduli were found to be slightly lower and the damping slightly higher on the specimens which had been exposed to fungal attack, but none of the differences were statistically significant, and the method appears of little value for diagnostic purposes, at least in the early stages of decay.

The damping is usually measured by the logarithmic decrement, which is equal to half the energy loss per cycle divided by the total energy of vibration. In static experiments, the existence of damping is reflected in the existence of a hysteresis in the stress/strain curve when the specimen is taken through a complete cycle of stress and strain (i.e. a cycle including both positive and negative values of stress and strain). In such a stress/strain curve, the energy loss is proportional to the area of the hysteresis loop and the maximum energy is proportional to the product of the maximum stress and maximum strain. It is thus possible to compare the logarithmic decrement measured in vibration

experiments with a corresponding quantity measured in static experiments. Some exploratory experiments on wood in torsion have been made along these lines. It is found that the logarithmic decrement and the corresponding quantity derived from static experiments are of the same order of magnitude, but that the latter one changes quite markedly with the limits of stress and strain between which the experiment is carried out.

The existence of hysteresis in the stress/strain curve shows that wood is not perfectly elastic. This is also shown by the existence of creep and stress relaxation in wood[37],[38]. The former involves an increase in deformation with time when the stress is held constant, and the latter a decrease in stress with time when the deformation is held constant. During the past year, an apparatus has been constructed in which a wood specimen is twisted by a known amount, and the stress required to maintain this twist is measured as a function of time. In the first experiment with this apparatus it has been found that the stress required to maintain a particular twist in a beech strip fell to about a quarter of its initial value over a period of four months.

Specific Heat and Heat of Wetting of Wood

Measurements have been completed of the specific heat and heat of wetting of beech sawdust at various moisture contents and temperatures. As discussed in previous annual reports, the observed specific heat of wood containing moisture is greater than the specific heat calculated from the specific heats and proportions of wood and water present, assuming a simple mixture law. It can be shown thermodynamically that the excess heat capacity of a system after a chemical reaction has taken place is equal to the rate of change in heat of reaction with temperature. Thus, if the sorption of water by wood is regarded as a chemical reaction, and the heat of wetting identified with the heat of reaction, an equation can be derived connecting excess specific heat with the temperature coefficient of heat of wetting. Examination of the experimental results on the beech sawdust shows that this equation is satisfied to within experimental error, and indicates that the above interpretation of the excess specific heat is the correct one[39].

Kelsey and Clarke[40] have recently measured the effect of temperature and moisture content on the heat of wetting of klinki pine, and have discussed the bearing of their results on the interpretation of the excess specific heat. Their values for change in heat of sorption with temperature are in reasonable agreement with those obtained at this Laboratory. This suggests that the specific heat of wood containing moisture does not depend greatly on species, a suggestion consistent with the results of Dunlap[41] who found the specific heat of dry woods to be independent of species.

Humidity-measuring Devices

Continuing work which has been in progress intermittently for some time, attention has been paid to the question of producing atmospheres of known relative humidity for calibrating humidity-measuring devices. As more results on saturated salt solutions become available, it is clear that these solutions do not provide a really accurate standard of relative humidity. Furthermore, in assessing the speed of response of humidity-sensitive elements, it is important to minimize any delay introduced by the humidity control, so that the observed speed of response is as nearly as possible that of the element itself. For these

reasons, a method of humidity control similar to that used in an oven developed in the Section a few years ago[42] is to be tried. This method involves the saturation of an air stream with water vapour and its subsequent heating to a higher temperature. A start has been made with the assembly of the necessary equipment and also with the testing of methods for measuring humidity by means of an anodized aluminium element.

Advisory Work in Physics

The principal enquiries dealt with during the past year have related to the following subjects: diffusion of gases in wood; the use of ultrasonics for the detection of flaws in plywood and in standing trees; statistical interpretation of experimental results; the theory of elastic constants; the torsion of a cylindrical rod of anisotropic material; the effect of moisture content on thermal diffusivity of wood; the assembly of data for the thermal properties of wood; the detection of metal in wood; the use of balsa as an insulating lining in vessels containing liquefied natural gas; and the electrical properties of wood.

EXTERNAL RELATIONS

During the year 9299 cubic feet of timber and 41 telegraph poles were brought into the Laboratory for test. This is 4188 cubic feet more than in 1954, the increase coming from the home-grown softwoods. There were 1426 cu. ft of hardwoods and 41 poles from overseas, with 725 cu. ft of hardwood and 7148 cu. ft of softwood from Great Britain. The following is the detailed list of timbers procured:

Name	Source	Quantity (cu. ft)	Section Testing
Imported			
Purpleheart	Commercial	12	Bending
African mahogany	Commercial	151	Composite Wood
African padauk	Commercial	70	Seasoning, Timber Mechanics, Mycology
Obeche	Commercial	66	Mycology and Entomology
Shorea smithiana	N. Borneo Forest Service	214	General test
Shorea parvifolia	N. Borneo Forest Service	215	General test
Dryobanalops lanceolata	N. Borneo Forest Service	192	General test
Yellow meranti (*Shorea* spp.)	N. Borneo Forest Service	157	General test
Muhuhu	Tanganyika Forest Service	295	General test
Pillarwood	Tanganyika Forest Service	364	General test
Home-grown			
Oak	Forestry Commission	129	Entomology
Beech	Forestry Commission	528	General work
Rauli	Forestry Commission	25	Bending, Timber Mechanics
Roble	Forestry Commission	5	Special test
English walnut	Commercial	11	Bending
Horse-chestnut	Commercial	27	Bending
Douglas fir (2 consignments)	Forestry Commission	909	General test
Sitka spruce	Forestry Commission	438	General test
Abies grandis (2 consignments)	Forestry Commission	739	General test

Name	Source	Quantity (cu. ft)	Section Testing
Lodgepole pine	Forestry Commission	70	General test
Japanese larch	Forestry Commission	1069	Special Service tests
Corsican pine	Forestry Commission	700	Special service tests
Scots pine	Forestry Commission	700	Special service tests
Douglas fir	Forestry Commission	473	Special service tests
Norway spruce	Forestry Commission	700	Special service tests
European larch	Forestry Commission	700	Special service tests
Scots pine (2 consignments)	Forestry Commission	650	General work

Timber Quality in Relation to Silviculture

The work in co-operation with the Forestry Commission on the quality of timber in relation to site and soil has continued. This work has now been in progress for over three years and to date eighteen consignments covering nine species have been tested and fifteen reports issued.

During the year seven consignments were procured, six of which were for full-scale tests and one consignment of five trees for preliminary investigation. They consisted of two parcels of Douglas fir and *Abies grandis*, and one each of western red cedar, western hemlock and lodgepole pine.

Nine reports were issued comprising two on Sitka spruce, three on Douglas fir, two on western red cedar, and one each on Corsican pine and western hemlock.

A composite edition of the six progress reports on Sitka spruce is being prepared. The specific gravity of the timber tested appeared to undergo a fairly regular decrease from sites progressively south to north in Great Britain, but further work will be required to confirm any regional differentiation throughout the country. The quality of Douglas fir grown in the north was found to be only slightly less than that of timber grown in the south.

Revision of Empire Timbers Handbook

The work on the book on Hardwoods was completed and will be published in April, 1956. Progress on the Softwoods book has been slow but it should be completed during the coming year.

Service Tests on Home-grown Conifers for Cable Drums

It was arranged with the Cable Drum Committee of the British Standards Institution that tests should be made on seven species of home-grown conifers to ascertain if these timbers were suitable for making cable drums. The Laboratory, in co-operation with the Forestry Commission, undertook to supply, saw, grade and season the timber for these tests, while the cable drum manufacturers would make the drums, put them into service and note their ability to stand up to wear and tear. Five species have already been supplied and the remaining two will be ready in the near future.

Trade Surveys

During the year work was started on two trade surveys to ascertain which

species of timber were being used, with the reasons for and against the use of each.

Twelve firms in the railway wagon and coach-building trade and five depots of the British Railways were visited, all making coaches or goods wagons. Much of the work done is to British Railways Specifications, but there is also a large amount for export, mainly to other Commonwealth Countries and Colonies.

The other trade surveyed was that of musical instrument manufacture. Visits have been made to 46 firms making various types of instrument and using a large assortment of timbers. Many of these timbers are not in common use, so visits were also paid to the timber merchants handling these timbers. This survey is well advanced and a report should be ready early in 1956.

Visits

It was possible this year to make more contacts with industry and eleven visits were made to timber merchants and users of timber in addition to the 63 firms visited on trade surveys.

Visitors and Education

A very heavy programme of visits was handled during the year. Their number increases annually, especially from members of timber-using industries. Timber merchants, furniture and joinery manufacturers, builders, architects, etc., sent 161 representatives. The numbers for the previous three years were: 1952=64, 1953=102, and 1954=139 persons.

The number of visiting members from technical colleges, institutions and associations was 210, consisting of 14 parties, which was an increase over the previous year. The Timber Development Association instructors' course of five members was run as usual, with a comprehensive programme of four days.

At the request of the Admiralty a series of courses was arranged for superintendents. Two 3-day courses were run this year, the second course being attended also by two of the staff of Lloyd's Register of Shipping.

The army sent eight officers from H.Q. Railway Home Group, who paid a day's visit to the Laboratory and were particularly interested in the work done on sleepers and structural timbers.

Two short courses for British Railways staff were arranged, one for three parties of ten supervisors attending for two days each. They were mostly interested in timber used in the permanent way. The other two-day course was for two parties of seven engineers responsible for carriage and wagon construction and other aspects of the upkeep of equipment. In addition, five senior engineers paid a one-day visit to the Laboratory.

Two parties from the Board of Trade and one party of 25 Colonial Public Works Department Engineers each paid a one-day visit to the Laboratory and were shown the work in progress.

Close contact has been maintained with the Forestry Commission. In addition to the exchange of visits by members of research staff, the Chairman, Lord Radnor, with the Deputy Director-General, Sir Henry Beresford-Pierce, paid a visit and two parties, one of nine technical officers and the other of 29 of the staff, came from the Forestry Commission Research Station at Alice Holt. A party of

36 Divisional Office staff from Cambridge and another from the Headquarters staff in London also came for one-day visits.

The number of overseas visitors during the year was 74, from twenty-eight different countries and Colonies. The visitors were from Australia, Bechuanaland, Burma, Canada, Germany, Gold Coast, Holland, India, Jamaica, Kenya, Malaya, New Zealand, Nigeria, North Borneo, Northern Rhodesia, Pakistan, Sarawak, Siam, Sierra Leone, Somaliland, South Africa, Spain, Sweden, Sudan, Tanganyika, Uganda, U.S.A., and Yugoslavia. The overseas visitors represented all classes of trade but most were timber merchants, foresters or engineers.

During the year the Utilization Officer in Tanganyika spent two weeks at the Laboratory, two British Guiana foresters attended for instruction for two months, and a member of staff from the Forest Products Laboratory in Australia spent four weeks, mainly in studying woodworking.

The four university schools of forestry were given the usual courses of instruction of two days each. The Imperial College of Science, Royal Holloway College, and the Architectural Association School of Architecture were given one day each.

The numbers of students from these institutes were:

Oxford University	24 students
Edinburgh University	12 students
Aberdeen University	12 students
Bangor University	15 students
Imperial College	15 students
Royal Holloway College	27 students
School of Architecture	38 students

Five courses for kiln operators were given during the year, the number of trainees being 44.

Advisory Work in External Relations

Technical enquiries dealt with by letter were 254, which were 54 more than the preceding year.

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F. W. HENDERSON,
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Aylesbury, Bucks.
March, 1956.

APPENDIX I

STAFF AT THE FOREST PRODUCTS RESEARCH LABORATORY

31st December, 1955

Director of Forest Products Research: F. Y. Henderson, C.B.E., D.Sc., D.I.C.

ADMINISTRATION

Assistant Director: J. Bryan, M.Eng., A.M.Inst.C.E.
Senior Principal Scientific Officers: K. T. St.G. Cartwright, M.A., D.I.C.; P. Harris, B.Sc.(Eng.), A.M.I.Mech.E.
Higher Executive Officer: R. D. Weeks, M.B.E.
Executive Officer: Miss D. Lacey.

SECTION OF WOOD STRUCTURE

Principal Scientific Officers: B. J. Rendle, B.Sc., A.R.C.S. (Officer in Charge); E. W. J. Phillips, B.Sc., Ph.D., A.R.C.S.
Scientific Officer: J. D. Brazier, B.Sc.
Experimental Officer: G. L. Franklin.
Assistant Experimental Officer: Miss L. M. Holtham.

SECTION OF PHYSICS

Principal Scientific Officer: R. F. S. Hearmon, F.Inst.P. (Officer in Charge).
Experimental Officer: J. Mc.C. Paton.
Assistant Experimental Officer: E. H. Adams.

SECTION OF SEASONING

Principal Scientific Officer: W. C. Stevens, M.A., A.M.I.Mech.E. (Officer in Charge).
Senior Experimental Officers: R. E. Hodge, A.I.Mech.E.; D. D. Johnston; G. H. Pratt; N. Turner.
Experimental Officer: A. R. Dean.
Assistant Experimental Officer: R. H. Wynands.

SECTION OF TIMBER MECHANICS

Principal Scientific Officer: F. H. Armstrong, M.Sc., M.I.Mech.E. (Officer in Charge).
Scientific Officers: A. J. Comben, B.Sc.; J. G. Sunley, M.Sc.
Senior Experimental Officer: A. J. Foord.
Experimental Officer: W. T. Curry.
Assistant Experimental Officers: G. R. Brock; Miss W. M. Fogerty; W. T. Hide.

SECTION OF WOOD PRESERVATION

Principal Scientific Officer: D. N. R. Smith (Officer in Charge).
Experimental Officers: Miss E. Lee; D. F. Purslow, B.Sc.; L. W. Redding.
Assistant Experimental Officer: R. Cockcroft.

SECTION OF CHEMISTRY

Principal Scientific Officer: R. H. Farmer, B.A., B.Sc., D.Sc.(Tech.), F.R.I.C. (Officer in Charge).
Senior Scientific Officer: R. A. Laidlaw, B.Sc., Ph.D.
Scientific Officer: Mrs. W. R. Carruthers, B.Sc.
Senior Experimental Officer: D. F. Packman, B.E.M.
Experimental Officer: L. C. Pinion, B.Sc.

SECTION OF MYCOLOGY

Senior Principal Scientific Officer: W. P. K. Findlay, D.Sc., A.R.C.S., D.I.C., A.I.C.T.A. (Officer in Charge).
Principal Scientific Officer: J. G. Savory, B.Sc.
Experimental Officer: E. C. Badcock.
Assistant Experimental Officer: Miss C. A. Clements, B.Sc.

SECTION OF ENTOMOLOGY

Principal Scientific Officers: R. C. Fisher, B.Sc., Ph.D., F.R.S.E. (Officer in Charge).
J. D. Bletchly, B.A., B.Sc., F.R.E.S.
Scientific Officer: M. G. White, M.A., F.R.E.S.
Senior Experimental Officer: E. C. Harris, F.R.E.S.
Experimental Officer: Miss J. M. Taylor, B.Sc.

SECTION OF WOODWORKING

Principal Scientific Officer: F. H. Armstrong, M.Sc., M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: K. J. S. Walker, M.A.
Senior Experimental Officer: R. Goodchild.
Experimental Officer: H. J. Endersby.

SECTION OF EXTERNAL RELATIONS

Principal Scientific Officer: F. G. O. Pearson, B.Sc. (Officer in Charge).
Senior Experimental Officer: A. V. Thomas, M.Eng.
Experimental Officer: Miss C. Webster.
Assistant Experimental Officer: Miss H. A. Fielding, B.A.

SECTION OF COMPOSITE WOOD

Principal Scientific Officer: R. A. G. Knight, B.Sc.(Eng.), M.I.Mech.E. (Officer in Charge).
Senior Scientific Officer: J. F. S. Carruthers, B.Sc., A.M.I.Mech.E.
Senior Experimental Officers: L. S. Doman; R. J. Newall.
Experimental Officer: R. W. Hudson.

SECTION OF PUBLICATIONS AND RECORDS

Senior Experimental Officer: C. J. N. McCracken, B.A., Dip. For. (Officer in Charge).
Assistant Experimental Officer: Miss E. M. M. Wood.
Temporary Assistant Experimental Officer: J. A. H. Broughton, B.Sc.

DRAWING OFFICE AND PHOTOGRAPHY

Senior Photographer: W. J. Baldwin.
Experimental Officer: E. A. Steel, A.I.Mech.E.

APPENDIX II

LIST OF PUBLICATIONS ISSUED DURING 1955

A. Stationery Office Publications

Forest Products Research, 1954

BULLETINS

No. 34. The Strength Properties of Timber. The 2-cm Standard for Tests of Small Clear Specimens. By F. H. Armstrong, M.Sc., M.I.Mech.E.

No. 35. The Machine Boring of Wood. By R. Goodchild.

LEAFLETS*

No. 8. The Common Furniture Beetle. (*Revised Edition*).

No. 12. Sap-stain in Timber. Its Cause, Recognition and Prevention. (*Revised edition*).

No. 16. The Steaming of Home-grown Beech. (*Revised edition*).

No. 20. The Treatment of Timber in a Drying Kiln. (*Revised edition*).

No. 42. Kiln-drying Schedules. (*Revised edition*).

No. 49. Grading of Sawn British Softwoods.

SPECIAL REPORTS

No. 9. The Strength of Timber Struts. By J. G. Sunley, M.Sc.

No. 10. Laminated Beams from Two Species of Timber. Theory of Design. By W. T. Curry.

B. Other Publications

BLETCHLY, J. D. A Little-known Borer in Imported Softwood: *Serropalpus barbatus* Schall. (Coleoptera, Melandryidae). Review of Literature and Recent Occurrences in Great Britain. *Forestry*, 1955, **28**(1), 67–72.

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* Obtainable gratis from the Laboratory (Princes Risborough, Aylesbury, Bucks.)

FARMER, R. H. & PACKMAN, D. F. The Production of Hardboard from Tropical Timbers.

I. Kempas (*Koompassia malaccensis*). *Colon. Pl. Anim. Prod.*, 1954, **4**(4), 293–309.

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APPENDIX III

REFERENCE LIST OF COMMON NAMES CITED IN TEXT

Abura = *Mitragyna ciliata*
Adwea = *Pachylobus barteri*
African mahogany = *Khaya* spp.
African padauk = *Pterocarpus soyauxii*
African pencil cedar = *Juniperus procera*
African walnut = *Lovoa klaineana*
Alan = *Shorea albida*
Alder = *Alnus glutinosa*
Andaman bulletwood = *Mimusops littoralis*
Aningueria = *Aningueria altissima*
Ash = *Fraxinus excelsior*
Ash, French = *Fraxinus excelsior*

Balsa = *Ochroma lagopus*
Baltic redwood = *Pinus sylvestris*
Beech = *Fagus sylvatica*
Birch = *Betula* spp.
Blue gum, Southern = *Eucalyptus globulus* & *E. bicostata*
Birch, Canadian = *Betula* spp.
Box, Brush = *Tristania conferta*
Brazilwood = *Caesalpinia echinata*
Brown sterculia = *Sterculia rhinopetala*
Brush box = *Tristania conferta*
Bubinga = *Guibourtia* spp.
Bulletwood, Andaman = *Mimusops littoralis*

Cedar, Western red = *Thuja plicata*
Canadian birch = *Betula* spp.
Cedar, African pencil = *Juniperus procera*
Cherry = *Prunus avium*
Corsican pine = *Pinus nigra* var. *calabrica*

Dahoma = *Piptadenia africana*
Douglas fir = *Pseudotsuga taxifolia*

East African mulberry = *Morus lactea*
Ebony = *Diospyros* spp.
Elm = *Ulmus* spp.
Elm, English = *Ulmus procera*
English oak = *Quercus robur* & *Q. petraea*
English walnut = *Juglans regia*
European larch = *Larix decidua*
European spruce = *Picea abies*

Fir, Douglas = *Pseudotsuga taxifolia*
Fir, Grand = *Abies grandis*
Fir, Noble = *Abies procera*
French ash = *Fraxinus excelsior*

Gaboon = *Aucoumea klaineana*
Grand fir = *Abies grandis*
Greenheart = *Ocotea rodiaei*
Gum, Southern blue = *Eucalyptus globulus* & *E. bicostata*

Hazel = *Corylus avellana*
Hemlock, Western = *Tsuga heterophylla*
Horse-chestnut = *Aesculus hippocastanum*

Indian rosewood = *Dalbergia latifolia*

Japanese larch = *Larix leptolepis*
Jelutong = *Dyera costulata*

Kapur = *Dryobalanops lanceolata*
Kévazingo = *Guibourtia* spp.
Klinki pine = *Araucaria klinkii*

Larch, European = *Larix decidua*
Larch, Japanese = *Larix leptolepis*
Landosan = *Aningueria robusta*
Lauan = *Parashorea, Pentacme* & *Shorea* spp.
Lodgepole pine = *Pinus contorta* var. *latifolia*

Mahogany, African = *Khaya* spp.
Makoré = *Mimusops heckelii*
Manio = *Podocarpus* spp. & *Saxegothea conspicua*
Manio macha = *Saxegothea conspicua*
Maple = *Acer* spp.
Meranti = *Shorea* spp.
Meranti bunga = *Shorea albida*
Morabukea = *Mora gonggrijpii*
Muchenche = *Piptadenia buchananii*
Muhuhu = *Brachylaena hutchinsii*
Mulberry, East African = *Morus lactea*
Myrtle, Tasmanian = *Nothofagus cunninghamii*

Niangon = *Tarrietia utilis*
Noble fir = *Abies procera*

Oak = *Quercus* spp.
Oak, English = *Quercus robur* & *Q. petraea*
Obeche = *Triplochiton scleroxylon*

Padauk, African = *Pterocarpus soyauxii*
Parana pine = *Araucaria angustifolia*
Pencil cedar, African = *Juniperus procera*
Pillarwood = *Cassipourea elliottii*
Pine, Corsican = *Pinus nigra* var. *calabrica*
Pine, Klinki = *Araucaria klinkii*
Pine, Lodgepole = *Pinus contorta* var. *latifolia*
Pine, Parana = *Araucaria angustifolia*
Pine, Pitch = *Pinus caribaea*
Pine, Scots = *Pinus sylvestris*
Punah = *Tetramerista glabra*
Purpleheart = *Peltogyne* spp.

Ramin = *Gonystylus* spp.
Rauli = *Nothofagus procera*
Red seraya = *Shorea* spp.
Redwood = *Pinus sylvestris*
Redwood, Baltic = *Pinus sylvestris*
Roble = *Nothofagus obliqua*
Rosewood, Indian = *Dalbergia latifolia*

Scots pine = *Pinus sylvestris*
Sepetir (Malaya) = *Sindora* spp.
Sepetir (Sarawak) = *Pseudosindora palustris*
Sequoia = *Sequoia sempervirens*
Seraya = *Parashorea & Shorea* spp.
Seraya, Red = *Shorea spp.*
Seraya, White = *Parashorea plicata*
Seraya, Yellow = *Shorea* spp.
Sitka spruce = *Picea sitchensis*
Southern blue gum = *Eucalyptus globulus & E. bicostata*
Spruce, European = *Picea abies*
Spruce, Sitka = *Picea sitchensis*
Sterculia, Brown = *Sterculia rhinopetala*

Tasmanian myrtle = *Nothofagus cunninghamii*

Utile = *Entandrophragma utile*

Wallaba = *Eperua falcata & E. grandiflora*
Walnut, African = *Lovoa klaineana*
Walnut, English = *Juglans regia*
Western hemlock = *Tsuga heterophylla*
Western red cedar = *Thuja plicata*
White seraya = *Parashorea plicata*
Whitewood = *Picea abies*

Yellow seraya = *Shorea* spp.

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